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Research Report

NUMBER

4

# Concerns for Sustainability

*Integration of Natural Resource and Environmental Issues in the Research Agendas of NARS*

Pierre Crosson
Jock R. Anderson

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# FOREWORD

In the past, farmers and farming systems were judged by their levels of production. Neither production costs nor the sustainability of production were given serious consideration. Now, however, the resource base for agriculture is shrinking and concern is rising for the sector's sustainability. Fast-growing populations depend on increasing agricultural production, while for ever more people, natural resources are not only inputs for agriculture, but are an important part of human heritage, to be conserved and renewed.

To help provide measures for these new concerns, attempts must be made to define sustainable agriculture. The authors introduce the concept of total productivity. This concept measures all the inputs and outputs of the agricultural system, including changes in the quality, quantity, and value of natural resources and the environment. Although problems in identifying these impacts are many, the total productivity concept may nonetheless help national agricultural research systems (NARS) to measure the costs and benefits of current production practices and of agricultural technologies proposed to be developed.

In addition to monitoring changes in total productivity, it is also necessary to investigate and understand why farmers adopt or reject certain technologies that adversely affect natural resources and the environment. In developing countries, NARS often lack the expertise for such work. Even more important, they have other priorities more directly related to overcoming existing hunger and malnutrition. Additional resources are required and new partners must be found to assist NARS in dealing effectively the local issues involved in effectively integrating natural resource and environmental issues in their traditional research agendas.

These issues must be addressed swiftly, with national and international assistance, in order to tackle foreseeable development and to find solutions to problems of sustainability that are acceptable to farmers and others. This book makes an important contribution to the discussion of sustainability, long-standing among scientists, but recently fueled to a wider audience by the 1992 United Nations Conference on the Environment and Development (UNCED).

Christian Bonte-Friedheirn
*Director General*

October 1993

# ABSTRACT

Achievement of sustainable agricultural systems requires farm technologies and management practices that indefinitely accommodate increasing demand for food and fiber at economic and environmental costs consistent with rising per capital welfare of people. To achieve sustainable agricultural systems in this sense the national agricultural research systems (NARS) in the less-developed countries must systematically integrate into their research agenda the effects of new technologies and practices on the natural resource base and environment. The concept of total productivity is useful in addressing this task because it can be defined to include *all* the benefits of new technology on the output side—both marketed commodities and unmarketed environmental services—and *all* the costs on the input side, including natural resource depletion and environmental damage. Changes in per capita total productivity over time thus provide an indicator of the sustainability of the new technologies developed through NARS research. The key problem in constructing measures of total productivity is the difficulty of measuring the unpriced environmental benefits and costs of new technologies. The physical processes by which the impacts are transmitted through the environment often are poorly understood. Assigning values to the impacts is problematic because they are not registered in markets, hence are unpriced. The capacity of most NARS to effectively incorporate natural resource and environmental issues in their research agenda also is problematic. Current NARS staffing reflects their commitment to traditional commodity research, which gives relatively little weight to natural resource and environmental impacts. They are particularly short of the social science skills they will need to give these impacts the weight they must have to assure agricultural sustainability. It is critically important that NARS strengthen their capacity to do the needed research. Absent this capacity, they will fall short of their responsibility to put their countries' agriculture on a sustainable path. Moreover, they will risk loss of control of the agricultural research agenda to other more aggressive institutions and groups that, in the interest of environmental protection, may underestimate the importance of increasing production of food and fiber.

# ARBEGE

Pour assurer la pérennité des systèmes de production, il importe de mettre en place des technologies agricoles et des pratiques de gestion qui permettront d'accéder indéfiniment à la demande croissante de produits alimentaires et de fibres, et ce à des prix économiques et à des frais environnementaux qui soient en harmonie avec l'é1evation progressive, considérée par personne, du niveau de vie des populations. Pour réaliser ce but, les systèmes nationaux de recherche agricole (SNRA) des pays moins développés doivent systématiquement intégrer dans leurs programmes de recherche, 1'étude des effets des nouvelles technologies et pratiques sur la base de ressources naturelles et sur 1'environnement. Le concept de productivité totale s'avère utile lorsqu'on assume cette tâche, puisqu'il peut être défini comme comprenant, sur le plan des résultats, *tous* les bénéfices—à la fois produits commercialisés et services environnementaux non commercialisés—ainsi que, du côté des intrants, *tous* les coûts, y compris la réduction des ressources naturelles et les dégâts causés à l'environnement. Ainsi, les modifications de la productivité totale, calculées par personne et sur une période de temps prolongée, fournissent un indice de la pérennité des nouvelles technologies mises au point par les SNRA. Le problème principal auquel on se heurte en cherchant à établir des mesures de productivité totale est qu'il est difficile de mesurer les avantages et les inconvénients pour 1'environnement de techniques nouvelles, car ils ne portent pas de prix. Les processus physiques qui entrent en jeu dans la transmission des résultats A travers 1'environnement sont fréquemment mal compris. De plus, les effets des technologies et des pratiques de gestion nouvelles ne figurent pas sur les listes des marchés et ne portent donc pas de prix, d'où la difficulté à leur attribuer des valeurs, mesurables. La question de la capacité des SNRA à intégrer de manière efficace les études relatives aux ressources naturelles et à 1'environnement dans leur programme de recherche pose également des problèmes. En effet, la composition actuelle des personnels des SNRA reflète un engagement dans la recherche traditionnelle sur les produits de base, qui n'accorde que relativement peu d'importance à 1'étude de l'impact sur les ressources naturelles et sur 1'environnement. En particulier, trop peu de chercheurs ont suivi une formation en sciences sociales qui leur permettra d'évaluer correctement ces effets, tâche nécessaire si l'on veut assurer la durabilité de l'agriculture. I1 est donc essentiel que les SNRA renforcent leur capacité à faire de la recherche dans ce domaine. L'absence de ces compétences signifiera qu'ils manqueront à leur devoir de guider 1'évolution de l'agriculture de leur pays vers la durabilité. Par ailleurs, ils courent le risque de voir passer le contrôle du programme de la recherche agricole de leurs mains à celles d'institutions et de groupes plus agressifs qui, dans leur souci de protéger 1'environnement, sous-estimeront peut-être la nécessité d'augmenter la production alimentaire et de fibres.

# RESUMEN

Los logros de los sisternas sostenibles agrícolas requieren tecnologías y practicas culturales que necesariamente adapten la creciente demanda de alimentos y fibras a los costos económicos y del medio ambiente según el aumento per-capita del bienestar de las personas. En este sentido para lograr sisternas sostenibles agrícolas; los Sisternas Nacionales de Investigación Agrícola **(SNIAs)** en los países en desarrollo deben sistemáticamente integrar en sus programas de investigación los efectos de las nuevas tecnologías y prácticas sobre la base de los recursos naturales y el medio ambiente. El concepto de la productividad total es útil para precisar tal objetivo porque esta puede set definida de tal manera que considere *todos* los beneficios de una nueva tecnología en el lado de la producción—como productos comerciables y como servicios no comerciables del medio ambiente—y *todos* los costos del lado de los insumos, incluyendo la depleción de los recursos naturales y el daño del medio ambiente. Así, los cambios en la productividad total per-capita a lo largo del tiempo proveen un indicador de la sostenibilidad de las nuevas tecnologías generadas en los SNIAs. El problema clave en cuantificar la productividad total es la dificultad de valorar los beneficios y costos del medio ambiente de las nuevas tecnologías a un precio determinado. Los procesos físicos por los cuales los impactos son transmitidos através del medio ambiente son poco entendidos. Determinar los valores de los impactos es un problema porque estos no están registrados en el mercado, entonces no tienen un precio. La capacidad de muchos SNIAs para incorporar efectivamente los temas de los recursos naturales y medio ambiente en sus programas de investigación también es un problema. El actual personal de los SNIAs reflejan su compromiso a la investigación tradicional por productos, lo cual deja relativamente poco espacio para estudiar los impactos sobre los recursos naturales y medio ambiente. Dicho personal tiene baja preparación en el análisis socioeconómico y necesitarán darle más importancia a estos impactos para, asegurar una agricultura sostenible. Es de suma importancia que los SNIAs fortalezcan su capacidad para tener la investigación necesaria. En la ausencia de esta capacidad, los SNIAs no podrán cumplir su responsabilidad de ubicar a la agricultura de su país en un sendero sostenible. Más aún, ellos podrían estar en una situación de no poder controlar los programas de investigación de otras instituciones y grupos que, en el interés de proteger al medio ambiente, podrían subestimar la importancia del aumento, de la producción de los alimentos.

# ACRONYMS

| | |
|---|---|
| CGIAR | Consultative Group on International Agricultural Research |
| EPA | environmental protection authority |
| FAO | Food and Agriculture Organization of the United Nations |
| GIS | geographic information system |
| IARC | international agricultural research center |
| ICARDA | International Center for Agricultural Research in the Dry Areas |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| ISNAR | International Service for National Agricultural Research |
| LDC | less-developed country |
| NARS | national agricultural research system(s) |
| NGO | nongovernmental organization |
| NR | natural resource |
| NRM | natural resource management |
| TAC | Technical Advisory Committee (to the CGIAR) |
| UNCED | United Nations Conference on the Environment and Development |

# EXECUTIVE SUMMARY

There now is much concern, reflected in Agenda 21 of the 1992 United Nations Conference on the Environment and Development (UNCED), that national agricultural systems in general use, and under development, may not be sustainable because they deplete the natural resource base and impose unacceptably high environmental costs. Accordingly, both the international and national agricultural research institutions are under mounting pressure to develop technologies that not only are economically attractive to farmers but also hold natural resource and environmental costs within sustainable limits. Such technologies form the core of a sustainable agricultural system, defined here as a system that indefinitely meets rising demands for food and fiber at economic, environmental, and other social costs consistent with rising per capita welfare of people served by the system.

### *Total Factor Productivity*

Total factor productivity is the ratio of all the outputs of the production system to all the inputs used in production. The outputs can be defined to include not only marketed commodities but also unmarketed services of the environment. An example is the value of wildlife habitat provided by farmland. The inputs can be defined to include not only the labor and purchased materials used in production, but also any costs of natural resource depletion and of damages to the environment.

Defined in these broad terms, changes in total productivity can be used to judge the sustainability of an agricultural system. Should per capita total productivity of the system remain the same or decline, the system would fail to satisfy the criteria for sustainability. The task of agricultural research, therefore, is to develop new practices and technologies that farmers will adopt and that sustainably increase per capita total productivity.

### *A Broader Research Agenda*

International and national agricultural research systems (the latter henceforth referred to as NARS) traditionally have sought to develop high yielding “commodity-based” technologies (for example, for rice, wheat, and maize) that would be widely adopted. The emphasis now on sustainability means that the research agenda must be broadened to include not only new commodity technologies but also improvements in natural resource management (NRM) as a source of total productivity growth.

The task of shaping the broader research agenda can be accomplished in two basic steps. The first is to construct a scenario of the growth of demand for the goods and services that the national agricultural system produces or potentially could produce over the next several decades. In the less-developed countries (LDCs), this demand will be overwhelmingly for food and fiber, although other nonstaple commercial farm products will also be important. However, the “agricultural system” also may produce other kinds of services, such as plant and animal habitat. Prospective increases in demand for these noncommodity services must also be included in the demand scenario.

The demand scenario provides NARS with guidelines as to the nature and scale of the challenge the agricultural system likely will face. The next step is to devise a research strategy that will meet the challenge by developing improved NRM practices and commodity-based technologies that together yield the requisite sustainable increases in total

productivity. A key part of the research strategy is to identify and measure the costs and benefits of alternative NRM and commodity technologies.

### *Identifying Costs and Benefits*

Devising a research strategy requires that the quantities and marginal social values of the outputs and inputs of the alternative technologies be estimated. Because they are marketed, this is relatively easy for commodity outputs and for labor and purchased inputs. For both the outputs and the inputs, market prices, with adjustments for various market distortions as appropriate, can be used as measures of marginal social values.

The more difficult task is estimating the quantities and marginal social values of unmarketed, therefore unpriced, environmental outputs and inputs. The impacts of production on the natural resource base must also be estimated. The natural resource (NR) impacts that count are those that affect the productivity in agriculture of land, water, and plant and animal genetic resources. The productivity effects are reflected in the economic costs of agricultural output. The loss of soil productivity because of erosion is an example of a negative NR consequence. Increases in soil productivity through NRM practices that build soil organic matter is an example of a positive NR consequence.

The environmental consequences of agriculture that count are those that affect the quantity or quality of resources not directly used in agriculture, and that are not priced. The value of wildlife habitat enhanced by NRM practices that increase the extent and diversity of vegetative cover is an example of positive environmental consequences. Damages to valuable nonagricultural ecosystems by pesticides or fertilizer in farm runoff water are examples of negative environmental consequences.

### *Measuring NR and Environmental Consequences*

Identifying NR and environmental consequences is relatively easy. Measuring them is difficult. Soil erosion, for example, is generally regarded as a major negative consequence of agricultural production, but none of the LDCs has reliable estimates of current rates of erosion and their long-term consequences for the productivity of land and water resources.

NR consequences of farm production affect the output of marketed commodities. Therefore, commodity prices can be used to value the NR consequences of agricultural production. NARS should recognize, however, that, because of possible market distortions, these prices may imperfectly reflect the real marginal social values of the commodities and the resources used to produce them.

Because they are unpriced, the environmental consequences of agricultural production generally are more difficult to value than the NR consequences. Economists have developed several techniques to deal with this valuation problem. The techniques seek to value the environmental consequences of different activities by estimating what the prices of the consequences would be if they were registered in markets. For example, the environmental consequences of sediment damage in a watershed might be measured by the difference in prices of two water-based recreational facilities in the watershed that are identical in all respects except that one facility has suffered sediment damage while the other has not. Such techniques make the valuing of environmental services conceptually commensurate with marketed goods and services. The advantage of this for agricultural research policy is that, in principle, the techniques permit direct comparisons of the NR and environmental consequences of alternative NRM practices and commodity technologies with the economic consequences. The disadvantage of such techniques for NARS is that they are data intensive and require highly developed skills in collecting and statistically manipulating large quantities of data.

### *The Time Horizon for Sustainability Research*

Research on sustainable agricultural systems will require NARS to adopt a time horizon measured in decades when they consider the economic, NR, and environmental consequences of the production systems they develop. A well-constructed demand scenario will provide the guidelines for thinking about these long-term consequences. But a time horizon over decades inevitably makes the difficult job of valuing NR and environmental consequences even more difficult. Relative commodity prices will surely change, as will the relative values societies put on environmental services. The question of the "correct" rate of discount also must be addressed. Some have argued that, where unique natural assets of overriding social value or the sustainability of basic life-support systems are at stake, intergenerational equity dictates that the "correct" rate of discount is zero. and that such assets and systems must be indefinitely preserved in their existing state.

In the end, the future values assigned to NR and environmental consequences, the identification of natural assets to be indefinitely preserved, if any, and the choice of discount rates must reflect social judgments by those in public agencies with responsibilities for resource management. The NARS likely would be among these agencies, but their influence on the judgments surely would vary widely from country to country, probably from not much to significant but not decisive.

### *Understanding Farm-level Adoption*

The NARS' research programs will fail if farmers do not adopt the improved NRM practices and technologies yielded by the programs. It is important, therefore, that NARS have some understanding of the policy, institutional, and other factors bearing on farmers' adoption decisions. For example, a strongly entrenched policy to limit imports of fertilizer and other purchased farm inputs should tend to increase the payoff to NRM research relative to research on technologies requiring substantial amounts of such inputs. Land tenure institutions that weaken property rights of individual farmers tend to discourage adoption of either NRM practices or commodity technologies with long-term payoffs. Analogous considerations apply to rights to water resources.

The property rights issue is especially relevant to strategies for managing environmental consequences of agriculture. Because farmers lack property rights in the resources affected by agriculture, they have little incentive to take account of the consequences when deciding to invest in improved NRM practices and commodity technologies. If NARS seek to control the consequences by changing on-farm practices, they must develop production packages that not only have the desired environmental effects, but are also economically attractive to farmers. This may not be the most cost-effective way to achieve the dual objectives of environmental improvement and increased commodity output. For example, because much sediment is stored throughout river basins, reducing on-farm erosion may have little short-term effect in reducing downstream sediment damages. It may be more efficient to establish an institution with basin-wide authority to invest in sediment management practices wherever in the basin the payoff to such practices would be highest. The point is that, because of the property-rights problem, putting the burden of dealing with the environmental consequences of agriculture solely on a **NARS** may not always be the socially optimal way to go.

### *Uncertainties and Regional Growth Differentials*

Estimates of the principal NR and environmental consequences of alternative NRM practices and commodity technologies combined with estimates of the corresponding economic consequences put NARS in a position to assign priorities among the alternatives. Differences in the degree of uncertainty about the estimated NR, environmental, and economic outcomes of the various alternatives will affect the assignment of priorities among them. So will policies that use agricultural research as an instrument to achieve more equitable patterns of income and employment growth among regions. These equity concerns would give added weight to alternatives that favor poorer regions, even if at some cost to advances in total productivity.

### *Capacity of NARS*

The addition of NRM and environmental issues to the task of already over-burdened NARS raises questions about their capacity to do the job. Present staffing of most NARS reflects their traditional commitment to commodity research. Their command of the professional skills needed to undertake research on NR and environmental issues is, in general, woefully weak. Social science skills in particular are inadequate.

In the present and prospective budgetary environment, NARS cannot expect to command the additional resources needed for the expanded task of NR and environmental research. They must find ways to use present resources more efficiently and they must seek alliances with other institutions, both national and international, with already established NR and environmental research skills.

There likely are no "best solutions" to the NARS' problem of building NR and environmental research capacities. It is important, however, that NARS take the lead in seeking solutions. Otherwise they risk losing control over the agricultural research agenda to other agencies less interested than they in promoting sustainable agricultural development.

### *Strategic Issues for the NARS*

An overarching challenge may be to convince NARS that the achievement of sustainable agricultural systems requires that NR and environmental research be a key component to be considered in their programs. Many NARS remain unconvinced that concern about NR and environmental issues is anything more than a rich-country obsession that they cannot afford. They are right not to be stampeded by apocalyptic visions of environmental destruction. What is needed is a balanced argument that NR and environmental issues require NARS' steady attention, just as other resource management issues.

To deal adequately with NR and environmental issues NARS will need to strengthen their analytic capacity in NR and environmental economics. The most direct way to do this would be to add economists with these skills to their staff. An alternative, probably less effective, would be to use consultants on an as-needed basis.

It will be critically important that the NARS not lose control of the agricultural research agenda with respect to NR and environmental issues. To maintain control the NARS will have to demonstrate that they recognize the importance of the NR and environmental issues and are competent in dealing with them. Otherwise those with a vested interest in promoting exaggerated negative estimates of the consequences may dominate research strategy in this field.

Institutions in the CGIAR should be an important source of assistance to NARS in dealing with NR and environmental issues. Some of these institutions have long included such issues on their research agenda, and now virtually all are giving the issues increased attention. The CGIAR institutions thus have accumulated, and are accumulating, a substantial body of knowledge about the NR and environmental consequences of alternative NRM practices and commodity technologies. NARS should actively strengthen their ties with these institutions so that they may tap this valuable store of knowledge.

# 1. INTRODUCTION

The push by the CGIAR (Gryseels et a]. 1992, p. 90 ff) to incorporate natural resource (NR) and environmental management issues in the research agenda of the IARCs and, indirectly, of the NARS poses a serious dilemma for the affected institutions. Dealing with these issues will greatly expand the responsibilities of the institutions at a time when not only are their budgets not expanding, they are, in fact, declining, with no end to the decline yet in sight. It is critically important, therefore, for the institutions to be clear about the objectives of their research programs and about the relationship of NR and environmental issues to the objectives. Without this clarity, the increasingly scarce resources available to the institutions will be inefficiently used and achievement of their objectives will be less satisfactory than it should be. This report is designed to assist the process of clarification and, in so doing, to provide some guidance to NARS about how they can more effectively shape their agricultural research programs.

The complexity of the subject matter arises partially because of the interlinking of many natural and human phenomena. Thus, this report may not constitute an easy read. Ready, pat solutions to the variety of institutional matters confronting research administrators and policyrnakers do not leap from the pages. Indeed, we would contend that any quick and easy answers to the NR and environmental challenges facing agriculture must be inherently flawed. Those who aspire to make responsible research decisions and defensible policy must pay a minimal price of coming to grips with the range of issues broached in the first four chapters.

# 2. CONCEPTUAL ISSUES

## 2.1 Sustainable Growth of Agricultural Output

There are many definitions of sustainable agricultural systems (Dixon and Fallon 1989, Pearce. Barbier, and Markandya 1990). The CGIAR in 1987 adopted the following: “A sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fiber needs, is economically viable, and enhances the quality of life for farmers and society as a whole.”

If one accepts that the primary objective of agricultural research is to develop production systems that respond in a sustainable way to rising human demands for food and fiber, the CG’s definition of sustainability seems less then ideal because it removes production as the central research objective. The following alternative definition impresses us as being more useful for grappling with NR and environmental issues in the context of agricultural research policy: a sustainable agricultural system is one that indefinitely meets rising demands for food and fiber at economic, environmental, and other social costs consistent with rising per capita welfare of people. Meeting rising demand is part of the definition because demand for agricultural output is, in fact, expected to rise for decades into the future. Rising per capita welfare is included because the welfare of so many people around the world presently is so low.

By this definition, enhancement of environmental quality and the natural resource base are relevant objectives of agricultural research only to the extent that they contribute to production under sustainable cost conditions. The definition does not imply that sustainability requires zero depletion of the NR base or zero environmental costs. Agricultural production that imposes some resource depletion and environmental costs can be sustainable as long as the costs of depletion and environmental damage are consistent with rising per capita welfare.

The difference between our proposed definition of sustainable agriculture and that adopted by the CGIAR is substantial. In the former, increased production is the objective of the agricultural system and the research that undergirds the system. In the CGIAR definition, increased production is only one of the objectives and not even the first. A more accurate statement that is probably more representative of contemporary CGIAR thinking about sustainable agriculture than the formally adopted 1987 CG definition is in the March 1993 Report of the TAC/Center Directors Working Group on the Ecoregional Approach (Annex 1, p.3):

> TAC sees the integration of research on commodity improvement with the conservation and management of natural resources as one of the organizational challenges facing the future of international agricultural research. It deserves emphasis because the need for increased productivity to feed burgeoning populations has sometimes been neglected in the international debate on environmental concerns. Resource conservation is not an end in itself. (Emphasis added.)

Some readers might feel that such concern with definitional details is pedantic, if not irrelevant. Our position is that an agreed perspective is necessary for identifying measures that can guide analysis of policies, approaches, and achievements in the field of NR and environmental work. It is to one such measure that we now turn.

## 2.2 Total Productivity as a Measure of Sustainability

The success of agricultural research has to date been measured largely by its contribution to increasing crop yields on farmers' fields and by the spatial extent of adoption of such yield-increasing technology. The increasing emphasis on including issues of NR and the environment on the agricultural research agendas of the IARCs and NARS results from a now general consensus that these past measures of research performance are too narrow. They ignore the fact that the improved technologies produced by agricultural research have, or often may have, consequences for the natural resource base and environment, both favorable and unfavorable. Such consequences, must be taken into account in any evaluation of agricultural research and in the setting of research priorities.

The concept of total factor productivity is better suited than a partial productivity measure such as crop yield as an indicator of whether an agricultural system is sustainable, as sustainability is defined here. It also is a better indicator of the success of agricultural research because it can, in fact if properly defined it must, take account of all the consequences of agricultural production, including effects on the natural resource base and the environment.

Total productivity is the ratio of all the outputs of the system to all the inputs used in production of the outputs. Lynam and Herdt (1989) define sustainability as nondeclining total factor productivity. This is a less demanding definition of sustainability than ours, which calls for rising total productivity expressed on a per capita basis. Moreover, the 1989 Lynam-Herdt definition did not include environmental costs among the inputs nor environmental benefits among the outputs. However, in a subsequent elaboration of their ideas these authors did pick up on their previously stressed importance of measuring these values in assessing the sustainability of the agricultural system (p.392). Herdt and Lynam (1992) proposed that "the appropriate measure by which to determine agricultural sustainability is total value of all output *(including* externalitites) produced by the system during one cycle divided by the total value of inputs *(including* externalitites) used by the system during one cycle of the system, using undistorted valuation and the social discount rate." (Emphasis added.)

The change over time in total productivity is a widely used indicator of agricultural performance. Its legitimacy as an indicator, however, depends crucially on correct measurement of both the outputs and the inputs of the agricultural system. As an indicator of sustainability (according to our definition), total productivity would have to include among the outputs not only crop and animal products and resource enhancements such as improved soil fertility but also environmental values, for example, the value of animal habitat created by the farm management practices adopted. Inputs must include not only the land, labor, fertilizer, etc. used in production but also the costs of resource depletion and environmental damage, for example, from losses of biodiversity from forest clearing to plant crops and run-off of sediment to streams.

Agricultural production systems frequently yield more than a single output, and they always require more than a single input. Consequently, measures of total productivity must be expressed as ratios of an index of output to an index of input. The output index for any given year is the weighted sum of the quantity of each component of output, where the weights are measures of the value, usually the prices, of each component, divided by the index of the same output components in some base year, times 100. The price weights may, for example, be those of a given year or of a base year. Thus an output index in a given year of 120 means that the price-weighted quantity of output that year was 20 percent greater than in the base year. Because in the simplest indexing scheme the price weights are the same in both the base year and the given year, the index is simply a measure of the percentage change in the quantity of production from the base year to the given year.

An input index is analogous. It measures the price-weighted quantity of inputs in the given year as a percentage of the price-weighted quantity of inputs in the base year, where the prices are either of the base year or of the given year. If the output index in a given year is 120 and the input index is 110, then the total productivity index for the given year is 120 divided by 110 (times 100), or 109, indicating that total productivity grew nine percent between the two years.

This simplified account of the measurement of total productivity implies that it is critically important to have correct measures of quantities and prices of inputs and outputs in both the given and the base years. Getting these measures is not always easy, even for outputs and inputs that pass through markets, thus leaving an information trail with respect to both quantities and prices. But resource depletion often is not registered in markets, and environmental damage by definition is not. Consequently, quantity and price data for these unmarketed inputs and outputs are usually missing or of poor quality. This makes it very difficult, if not impossible. to include them in total productivity measures. The more important that these unpriced inputs and outputs are relative to those that are priced, the less reliable total productivity indexes will typically become as measures of sustainable agricultural performance. The difficulty of incorporating unpriced inputs and outputs in total productivity indexes is only one of the problems in constructing such indexes, although its importance in particular should not be underplayed. Difficult problems also arise even for priced inputs and outputs, whenever the quantities and relative prices of these change rapidly over time. The latter issue has been the subject of a large theoretical and empirical literature nicely and cogently summarized and distilled by Alston, Norton, and Pardey (1994, section 4.1.3). In their review of workable and reasonable approximative procedures that can be employed in practical productivity analyses, they emphasize the implicit assumptions about the concerned economic agents making optimal adjustments to quantities in response to perceived price signals. For the issue of unpriced elements, the lack of even an implicit optimizing framework thus remains something of a thorn in the heel of any applied indexing approach. Notwithstanding the difficulties of both theoretical niceties and empirical work in a changing and uncertain world, we press on with our advocacy of the use of total productivity as the one unifying principle in a field of otherwise disparate and disjoint elements.

The lack of quantity and price information for NR and environmental consequences of production is, of course, not a problem peculiar to constructing measures of total productivity. The lack infects the whole enterprise of formulating strategies for agricultural research and other policies aimed at achieving sustainability. In the literature dealing with these issues there appears to be a consensus that, typically, estimates of the quantities of resource depletion and environmental damage are easier to get than estimates of the correct prices to attach to the quantities. That is, it is easier to estimate, for example, the quantity of crop-yield loss resulting from erosion or the quantity of agricultural chemicals in potable water supplies, than it is to estimate the resulting losses of social value. With the absence of markets in which to register the value of these losses, how are they to be estimated? In discussing this question, Lynam and Herdt (1989, p. 388) argue that the losses should be priced to reflect long-term values to society. Lynam and Herdt do not discuss how these long-term values might be determined, but they do comment on the differences between economists and ecologists in this respect. Economists seek, so far not very successfully, to estimate these values as if they were registered in markets. Ecologists, according to Lynam and Herdt, argue for a set of prices (or weights) that reflect long-term preservation of an ecologically defined ideal state. We have more to say about these valuation issues in sections 3.5-3.7.

The difficulty of measuring the costs and benefits of agricultural uses of natural resources and the environment is not an argument against including the costs and benefits in the concept of total productivity. Their inclusion is essential to a correct interpretation of agricultural productivity performance over time. Inclusion makes clear that the costs of agricultural uses of natural resources and the environment are conceptually no different from the costs of using all the various forms of human-made resources; and that the NR and environmental benefits of agriculture are conceptually no different from the benefits received from the production of grains, animal products, and other commodities. An accurate judgment of agricultural productivity changes *requires* that the natural resource (and environmental) consequences of agriculture be included in the concept and measurement of productivity.

In Chapter 3 of this report, the implications for NARS of these issues are discussed, and considerably more is said about the problems of valuing unpriced resource depletion and environmental damage. The point here is that, as a conceptual matter, these problems must be squarely faced and somehow resolved if informed judgments are to be made about agricultural research strategies and policies to achieve sustainable agricultural development in the LDCs.

The definitions preferred here for sustainable agriculture and for total productivity as an indicator of sustainable performance of the agricultural system capture all the NR and environmental consequences of agricultural production. The definitions, therefore, are wholly consistent with the CGIAR's push to include NR and environmental issues in the research agendas of the IARCs and the NARS. Moreover, the definitions can incorporate as narrow or broad a specification of output as may be relevant to any specific case. If, for example, a NARS seeks to develop a sustainable system for producing a single crop, say maize, the definitions can be used to evaluate the performance of the system, noting that any incidental benefits of the system in addition to maize production would have to be included among the outputs of the system. The value of any NR depletion or environmental damage would also have to be included among the inputs. If the research objective is to develop mixed cropping systems, or mixed crop/livestock systems, the same argument applies. If agriculture is defined more broadly and fashionably to include forestry and fisheries, research to expand the productivity of those systems also can be evaluated by the standards set out in these definitions.

## 2.3 Sources of Sustainable Growth in Agricultural Productivity

Taken at the farm level, all sources of productivity growth can be put in one or the other of two categories: improvements in natural resource management (NRM) and improvements in technology. Research to increase productivity through new technology such as that embodied in improved cultivars is, by way of convenient shorthand, often referred to as commodity research. That practice is adopted here for continuity and brevity.

Productivity growth through improved NRM can take four forms:

- practices that restore the productivity of degraded natural resources, for example, mulching and planting leguminous crops to restore the fertility of degraded land;
- practices that slow rates of natural resource degradation, for example, terracing or conservation tillage to reduce soil erosion;

- practices that increase the productivity of poor quality but not degraded natural resources, for example, bunding, hedging, or some comparable practice to slow runoff and increase water infiltration on dryland soils;
- practices that increase the productivity of good quality natural resources, for example, improvements in management of water on irrigated land to avoid or reduce waterlogging and salinity buildup.

Total productivity growth through improvements in technology, reflecting commodity research, are easily understood because traditionally that has been the principal source of such growth. To understand the total productivity consequences of new technology and to rank the payoff to commodity research relative to NRM research, requires a complete specification of the inputs required by the technology and their prices, including of course the quantities and prices of NR and environmental inputs.

A major task in devising an agricultural research agenda, whether in IARCs or NARS, is deciding which among the alternative sources of productivity growth promises the most favorable return to resources invested in agricultural research. The tenor of many contemporary debates and discussions suggests that the increasing concern about sustainability inevitably favors more emphasis on improved NRM relative to commodity research.

It is easy to agree that, under present circumstances, the payoff to increased NRM research in the IARCs and NARS probably is higher now relative to commodity research than earlier. It is not as easy to be convinced, however, that the indicated shift in favor of NRM research is as marked as some commentators imply. There are a couple of reasons for this reserve. One is that most agricultural research, even broadly defined to include forestry and fisheries, must necessarily be commodity research. The rationale for such research is that it is needed to meet prospective massive increases in demand for food and fiber by people in the LDCs. Food and fiber are commodities. To be sure, sustainable commodity production must give proper weight to all the NR and environmental consequences of production, and this will require increased NRM research, but the prime objective of the research remains increased productivity in commodity production.

The second reason why we think some observers may overstate the case for increased priority for NRM research relative to commodity research is our belief that, at least for the past 15 or 20 years, commodity research already included a substantial amount of attention to NRM issues. Lynam and Herdt (1989, p. 389) note that, with respect to replenishment of soil nutrients, NRM research aims to improve soil quality and enhance the rates and efficiency of existing biological processes that control nutrient cycling and pest populations. "This leads to research on topics such as enhanced biological nitrogen fixation, more efficient mycorrhiza strains, ecosystem mimicry in cropping patterns, crop rotations and multiple cropping, and biological control of insects, diseases, and weeds—*topics which, even in the 1970s and 1980s, formed a considerable portion of the agenda at international agricultural research centers."* (Emphasis added.) Among the "old" CG IARCs, two institutions, ICARDA and ICRISAT, although commodity-oriented in much of their research program, have always given major attention to NRM.

The point of these observations is not to deny the importance of increased research on NRM but to note that, if the LkRCs (there seems to be no comparable information about NARS) have been doing NRM research for a considerable time, the payoff to additional research of that kind may not be as high relative to commodity research as the statements quoted above might suggest.

Dr. K. Jain, in an unpublished ISNAR memorandum on the sustainability perspective, made a strong argument for increased NRM research relative to commodity research. The grounds for the argument are that much of future increases in food production in the LDCs will have to come from dryland areas where much of the soil is of poor quality and research to increase the productivity of these lands has lagged. Development for dryland areas of management techniques that increase conservation of soil water and improve soil fertility are especially important. Jain boldly recommended a specific allocation of research resources between NRM research and commodity research. He suggested that a good rule would be that in organizing research for dryland agriculture two-thirds of the scientific and other resources should be allocated to resource management research and one-third to genetic improvement of the commodity. Such a relative resource allocation could, he argued, be defended by taking into consideration the fact that yield-improving genetic technologies for such lands will be neither very effective nor sustainable unless the problems of resource management are fully addressed.

We do not accept Jain's specific recommendation. His more interesting point, in our judgment, is his suggestion that, in fact, research on NRM complements that on commodities. The report of the TAC/Center Directors Working Group on the Ecoregional Approach (March 1993) also states that "Future productivity increases will require the adoption of more integrated approaches to agricultural production, combining genetic enhancement with the improved management of the natural resource base." Lynam and Herdt (1989, p. 390) argue that "dividing research solutions to the sustainability problem into two distinct and competing strategies is counterproductive; to be successful the biological research agenda will have to complement the continued use of inputs in the intensification of farming systems in the tropics."

This idea might be extended metaphorically by observing that much commodity research is all about manipulating the genotype resource in exploiting genotype/environment interactions; taking aboard greater attention to NRM matters amounts to placing new emphasis on manipulating the environment contribution to the interaction.

Clearly the issue of the proper weights to be given to NRM research and commodity research, and within NRM research to the four sources of productivity growth, cannot be settled at the conceptual level. The weights will vary among countries at any given time, and for any country will change over time in response to changing conditions of demand and resource constraints. Accordingly, each NARS will have to determine the weights appropriate to its own particular situation, and be prepared to change the weights as underlying conditions change.

It is important to keep in mind that in setting relative weights for NRM and commodity research, NARS must take account of the economic consequences of improved NRM practices and commodity-based technologies as well as the NR and environmental consequences. For this report, however, we deal only with the NR and environmental consequences because it is increasing concern about these that now is forcing new thinking about the research agenda of the IARCs and NARS.[1]

This may be a convenient juncture to link the present theme to other dimensions of agricultural research planning and policy-making. The now-familiar ground of economic assessment in research evaluation and priority setting, ground that has been so well ploughed at ISNAR, features explicit attention to efficiency, equity, and food security. In adding sustainability concerns and a focus on NR and environmental consequences. we are essentially adding another dimension to the assessment framework. In its simplest imaginable form, this dimension might become just another variable that enters into a scoring model (Graham-Tomasi 1991, p. 78). In this way it can contribute to influencing the nature and scope of the national research agenda. If the new dimension is represented, however, by a

1 For a discussion of incorporation of economic consequences of alternative practices and technologies in determination of research priorities see Alston, Norton, and Pardey (1994).

well-estimated intertemporal index of total productivity, direct incorporation of the index in a scoring model (or in some juxtaposition with measures of economic surplus, for instance) will require that considerable care be taken to avoid double counting or worse. This is because many of the economic efficiency aspects are already captured in the total productivity measure.

An important advantage of total productivity as an indicator of performance in achieving sustainability is that conceptually it explicitly captures in a single measure the economic consequences of both NRM and commodity research as well as the NR and environmental consequences. A lag in the growth of total productivity, as defined above, combined with evidence of rising costs of NR depletion and environmental damage would suggest that more weight should be given to NRM research relative to commodity research. A lag in productivity growth with evidence of constant or declining costs of NR depletion and environmental damage would suggest relatively more emphasis on commodity research.

The critical point is to keep uppermost the complementarity of NRM and commodity research. Complementarity in this context means that the payoff to either one of these types of research depends to some extent on the payoff to the other. If the push to incorporate NR and environmental consequences into the agricultural research agenda obscures complementarity, the pursuit of sustainable agriculture in the LDCs will be impeded.

Our enthusiasm for the broadly defined total productivity measure is driven by its conceptual simplicity and its harmonizing unification. While we have emphasized several measurement challenges to be faced in employing it, we have not argued that work with it has to constitute a search for the Holy Grail. Different applications and decisions will require different levels of precision. For some policy work it may be that crude, almost “back of the envelope” estimates will serve the purpose adequately. Work with the measure can be tailor-made to the specificities of particular research policy decisions that will include the level of aggregation, accuracy of data compilation, scope of included environmental dimensions, and so on. As experience in application grows, the process of assessing total productivity will evolve.

# 3. IMPLICATIONS FOR THE NARS,

## 3.1 A Demand Scenario and NR and Environmental Consequences

For NARS discussion in Chapter 2 has important implications for devising a strategy to incorporate NRM and environmental issues in their research programs. This chapter and the one following draw out those implications. The focus is on issues that any NARS likely would face. Of course, the relative importance of each of the issues would differ among NARS, depending on their specific circumstances.

We start from the assumption that the objective of any NARS in a LDC is to increase the productivity of resources employed in agriculture for meeting demands for food, fiber, and other outputs that agriculture might provide. We assume also that NARS should seek this objective in a sustainable way (i.e., one such that the demands on the system can be indefinitely met at economic, environmental, and other social costs consistent with rising per capita welfare of the people in the nation).

This perspective suggests that the task of any NARS can be divided in two basic parts. The first, and almost surely the easier part, is to construct a demand scenario to provide insights to future demand pressures on the country's agricultural system. The second, and far more difficult part, is to design and implement a research program that will increase the total productivity of agricultural resources enough to sustainably meet the demand scenario.

The rest of Chapter 3 discusses the principal issues that any NARS must face in devising its research program. It then provides some suggestions about how the issues can best be addressed. A central research policy issue is how to assign weights between the two sources of potential productivity growth-improvements in NRM and new technology-recognizing that in many if not all circumstances the two sources will be complements, not substitutes.

Before beginning the discussion, we think it important to point out that any country, or region within a country, in principle, has the option of substituting imports for domestic or local, production to meet domestic or local demands. Consequently, should demands placed on the national or local system begin to threaten sustainability, the import option could be used to avoid the threat. Other things being the same, the more attractive the import option on economic and political grounds, the less the need to invest in NRM or commodity research. Indeed, the payoff in income and environmental improvement to more investment in strengthening the import option—such as by improving port facilities and the internal road system—may, at the margin, be higher than the payoff to more investment in agricultural research. Further discussion of the import option is outside the bounds of this report. Every country, however, and every NARS, should give some attention to the option in devising an agricultural research strategy.

## 3.2 The Importance of a Demand Scenario

In all countries, especially the LDCs, the demands on the agricultural system are overwhelmingly for food and fiber. In the LDCs, that likely will continue to be the case into the indefinite future. Nevertheless, the agricultural system also can produce other kinds of services, such as plant and animal habitat and scenic amenities, for which there is already a demand in most countries. In many countries these kinds of demand will likely increase in the future. As incomes increase, demand for these kinds of services may rise faster than demand for food and fiber.

Specification of a demand scenario should help to make NARS responsive to the ecoregional approach that the CGIAR now is proposing as an organizational paradigm for the research programs of both IARCs and NARS. Knowledge of the agroclimatic conditions of the country will provide NARS with guidelines as to which regions would be best suited to produce the components of the demand scenario, whether they be different crops, animals, or nonproduct services such as improved plant and animal habitat. We consider this role of the demand scenario in helping to organize the research program important. Our suggestion is that NARS begin with a specification of the demand scenario, and use information about agroecosystems as a guide to where within the country production to meet the demand could best be located. The research program then could be shaped to develop technologies and management practices for use in the selected locations, taking the agroecosystem characteristics as defining both opportunities and constraints. As with all strategic and applied research, the most efficient approach to the implemented research may involve focused attempts to borrow research results and techniques from beyond the national borders.

The point here is that no NARS can design an effective research program without first having developed a scenario of present and future demand for commodities and other services, including foreign demand, to which its agricultural system can, or potentially could, respond. The scenario must include a specification of the different commodity and service categories of demand and some notion of the strength of the various categories.

The content of the demand scenario will, of course, depend on the specific demand conditions of the country: population and per capita income growth; preferences of the population among different kinds of food, reflecting religious, cultural, and other characteristics; and, not to be overlooked, the possibility of producing for foreign demand (Bonte-Friedheim and Kassam 1993). Despite the demand differences among countries, experience suggests that for most if not all demand for animal products, and hence for feedgrains, will tend to rise with rising per capita income. Crosson and Anderson (1992) cite recent World Bank studies showing this tendency in the fast-growing economies of East and Southeast Asia, but the tendency now is widely accepted as a common consequence of rising per capita income.

## 3.3 Defining and Measuring NR and Environmental Consequences

The bulk of the discussion here deals with problems of defining and measuring the NR and environmental consequences of agricultural production as necessary steps toward setting weights for NRM and commodity research.

As indicated above, we devote most attention to NRM because this source of potential productivity growth is less studied and presumably not as well understood as commodity research among NARS. We note again, however, that wherever NRM and commodity research are complements, the productivity potential of either cannot be properly assessed without taking the other into account.

For any NARS, the objective of both kinds of research, is to increase the total productivity of agricultural resources to meet the demand scenario for the country. In addressing the question of how to increase total productivity through NRM and commodity research, NARS must understand the input and output consequences of the NRM practices and technologies that each type of research would yield. We suggest that the necessary understanding can best be achieved in three steps:

- identify the NR and environmental consequences with which NARS must be concerned;
- measure the consequences;
- analyze why farmers sometimes adopt NRM practices and technologies that generate adverse consequences or fail to adopt favorable practices and techniques.

With this understanding of the nature, magnitude, and causes of NR and environmental consequences, NARS would be in a position to devise strategies that assign weights to NRM and commodity research. The next task, then, would be to build or strengthen the NARS capacity to implement the research strategy.

In the rest of this chapter we discuss the three steps to achieving the necessary understanding. We discuss issues of assigning weights and building capacity in Chapter 4.

## 3.4 Identifying NR and Environmental Consequences

We define NR consequences as those that affect the productivity in agriculture of land, water, and plant and animal genetic resources. The productivity effects are reflected in the economic costs of agricultural output. Environmental consequences are those that affect the quantity or quality of resources not used in agriculture, and that are not priced.

Erosion-induced losses of soil productivity are an example of negative natural resource consequences. Other things being the same, losses in soil productivity would increase the economic cost of farm output. Increases in soil productivity induced by farm management practices that build organic matter are an example of a positive natural resource consequence. Other things being the same, an increase in soil productivity would reduce the economic cost of farm output.

Farm management practices that increase the extent and diversity of vegetative cover of the land enhance animal habitat value, thus benefiting hunters, animal watchers, and people who take pleasure from the knowledge that animal habitat is improved, even though they are neither hunters nor watchers. Typically these habitat values are not priced because, unlike farm commodity output, there are no markets for such values. Habitat improvement, therefore, is an example of a positive environmental consequence of agriculture. It follows, of course, that destruction of habitat by, for example, clearing forests or draining wetlands, is an example of a negative environmental consequence.

The exhaustion of soil nutrients under continuous cropping is a negative NR consequence. Although this form of NR degradation has received much less attention than the productivity effects of soil erosion, evidence suggests that it is a factor in the generally poor crop yields in Africa over the past several decades.

Concern has been expressed for several years about the slowdown and, in some areas, decline in rice yields in parts of Asia. The reasons for this are not well understood, but some adverse effects of the current intensive management practices on the NR base, probably the soil, is suspected.

Some other examples of NR and environmental consequences can be given. Reductions in crop yields because the overuse of insecticides has built up genetic resistance in crop-damaging insects is an example of a negative natural resource consequence. Damages to nonagricultural ecosystems by herbicides, insecticides, or nutrients in farm runoff are examples of a negative environmental consequence. The increase in soil fertility in floodplains by deposition of soil eroded from upstream farms is an example of a positive NR consequence. The creation of wetlands where sediment has clogged drainage is an example of a positive environmental consequence.

To identify the kinds of NR and environmental consequences that may be significant is easy. Measuring their significance is both critically important and extraordinarily difficult. Accurate calculation of the total productivity payoff to alternative types of research requires that both the physical dimensions and the marginal social values of the two kinds of consequences be measured. Both kinds of quantity consequences are difficult to measure. Measurement of value consequences is even more difficult, particularly the marginal social value of the environmental consequences.

## 3.5 Measuring NR Consequences

For many if not most NARS, land degradation or improvement is an important NR consequence of agricultural production. Degradation is the principal concern and we begin with that. Subsequently, however, we note several practices that can enhance land quality.

Crosson and Anderson (1992) reviewed the evidence on land degradation around the world and found it extraordinarily skimpy. No LDC has comprehensive data indicating either the extent of presently degraded soils or the rates of degradation from current practices. Consequently, comprehensive estimates of the productivity consequences of degradation are not presently possible for any of these countries. Oldeman, Hakkeling, and Sombroek (1991) published a map of degraded land around the world that might provide a start toward collecting some of the necessary information for some countries. For most countries, however, the map is not in sufficient detail to provide much guidance as to the extent of land degradation, let alone its productivity consequences.

The absence of reliable information about soil degradation is a major constraint on the ability of NARS to devise efficient strategies for NRM research. Sample surveys could perhaps provide the missing information but, if done properly, such surveys probably would cost more than many LDC ministries of agriculture or NARS would be willing to pay.

Where surveys are judged too expensive, lower cost procedures may nonetheless provide sufficient information to form some rough judgments about the productivity significance of soil degradation. Experienced people, well trained in the soil sciences, through visual examination of a landscape often can make useful judgments about the extent of soil degradation and the likely productivity consequences, positive or negative, of alternative fanning practices. Although a NARS may not want to base a NRM research strategy on such judgments, the judgments may help in deciding where to locate research projects to develop better information about soil degradation-productivity relationships. If continued long enough—probably rather more than 10 years—such studies will begin to provide the kinds of information needed for better informed decisions about NRM research on soil degradation.

Finally, NARS might learn something useful about the productivity effects of soil degradation by inference from studies done in other regions with similar soil and climate regimes. Such studies in the LDCs are not numerous. We found only three in our search for such material although our search was not exhaustive (Crosson and Anderson 1992). The three studies were by Bronger and Bruhn (1988) on the red soils that cover some 700,000 $km^2$ in India, by Lai (1984) in Nigeria, and by Bishop and Allen (1989) in Mali. The work by Bishop and Allen is worth more than a word here because it nicely illustrates the point that studies of erosion-productivity relationships in one area may provide useful insights to the relationships somewhere else. The study is interesting also because it highlights the kinds of data and analytical techniques needed to do such studies. The following account of the Bishop and Allen study is from Crosson and Anderson (1992, p. 38):

> Briefly, Bishop and Allen (1989) used the universal soil loss equation (developed in the United States but here adapted to West African conditions) to estimate cropland erosion in an area of Mali comprising about one-third of the nation's most productive cultivated land. They then used regression models of the erosion-yield loss relationships developed at the International Institute for Tropical Agriculture (IITA) in Nigeria to estimate the impact of erosion on crop yields in Mali over a 10-year period. Crop and input prices were used to value the net loss of crop output per hectare per year over the 10 years. The losses were assumed to be cumulative, i.e., the second year loss equals the loss that year plus the first year loss, and so on for the subsequent years. The annual stream of 10-year losses was discounted and summed to get the present value of the per hectare cumulative loss. This estimate was multiplied by the number of hectares in the crops studied in the country as a whole to get nationwide estimates of the losses.

We carry no brief here for the specifics of the Bishop and Allen results, although we believe that the approach they took was well suited to the objective they had in mind. That is our point: their study illustrates how data and analytical techniques developed to analyze erosionproductivity relationships in one region or country may fruitfully be used to illuminate those relationships in another region or country.

Soil and water degradation from waterlogging and salinity buildup associated with irrigation is another important form of NR degradation. Because it is associated with irrigation, this form of degradation is spatially much more confined than degradation resulting from soil erosion. Waterlogging and salinity buildup nonetheless are important because irrigated agriculture is so widespread, especially in Asia. This form of NR degradation is not now a major problem in Africa because irrigation there is relatively undeveloped. There is untapped irrigation potential in Africa, however, so the waterlogging-salinity problem could, without careful management, become significant in the future.

The effects of waterlogging and salinity have been more studied than the effects of erosion on soil productivity. NARS in countries such as India (World Bank 1991) where these studies have been done can draw on them in shaping their NRM and commodity research programs. The studies may also be of use to NARS in other countries which have irrigation or are exploring the possibility of building irrigation projects.

The discussion has dealt with measurement of the quantitative consequences of agricultural production. Such measurements are necessary but not sufficient for calculating the impact of the consequences on total productivity. The marginal social values—prices in the case of NR effects—of the consequences must also be measured.

Because the NR consequences of farm production practices affect the output of marketable commodities, commodity prices can be used to value the consequences. The work of Bishop and Allen (1989) cited above illustrates this. The quoted statement describing their work indicates that they used crop and input prices to value the erosion-induced net loss of crop output in Mali. The same procedure could be used to value measured increases in soil productivity achieved through improved NRM practices and also to value both the negative effects on productivity of waterlogging and salinity and the positive effects of improved practices to reduce these damages.

The fact that in many poor rural areas the productivity consequences of NRM practices would mostly likely affect only on-farm consumption would not seriously impede the use of prices to value the consequences. Some part of the affected commodity output would invariably be marketed. Consequently, the needed price information would be available.

Of course, questions might legitimately be raised about how accurately the available market prices reflect the “true” social marginal values of the affected outputs and inputs. “True” here has the special meaning given to prices in neoclassical economics: output prices measure the marginal social value to consumers and input prices measure the marginal social opportunity costs of the inputs when all markets are perfectly competitive and there are no externalities in either consumption or production. These conditions are never perfectly met anywhere. And, even if they were, philosophical considerations not included in neoclassical economics (for example, concerns about equity within and across generations) raise questions about how accurately “true” prices measure real social values.

According to these arguments NARS should not blindly accept market prices to value the NR consequences of farm practices. NARS should recognize the high probability that these prices will to some extent reflect international, national, and local policies and other conditions that make them imperfect measures of “true” social values. This is not an argument, however, for casting the price information aside. The question must be asked: What other measures of the marginal social value of NR consequences would be better? Unless some obviously better alternative is available, market prices, perhaps with such rough adjustments as a NARS, or some higher authority such as a ministry of finance thinks appropriate should be used.

## 3.6 Measuring Environmental Consequences

Recall our definition of the environmental consequences of farm practices-consequences that affect the quantity and quality of resources not used in agriculture and that are not priced. In our judgment the most important potential environmental consequences are the following: the downstream effects of sediment and agricultural chemicals in farm runoff on aquatic ecological systems and on municipal, industrial, and recreational uses of water; changes in plant and animal habitat from land clearing and draining; and the off-farm health effects of drinking farm-polluted ground or surface water and eating pesticide-tainted food. Not all of these environmental consequences will be important in every country. Some of them may not be presently important in any country. In designing their research programs, however, NARS must take the long view of the environmental (and NR) consequences of the NRM practices and commodity technologies they propose to develop. Without a long view, consequences now properly regarded as molehills may in time emerge as mountains.

Note that we do not include on-farm human health effects of pesticides, whether in groundwater or through poisoning in application, as an environmental consequence. We regard these effects as NR consequences because, in principle, they affect the productivity of labor on the farm and hence would be reflected in on-farm production costs. To the extent that negative health consequences on agricultural workers and others are not captured in on-farm effects, these would constitute environmental consequences and should be accounted for as such (Antle 1993).

Nor do we include emissions of methane from farm animals and rice paddies as an environmental consequence, even though these emissions contribute to global warming. We make this decision because, in our judgment, no single country, not even China or India, either now or in the future, emits or is likely to emit enough methane from farm sources to make a significant difference in global warming. Consequently, under this assessment of present circumstances, farm methane emissions are not a consequence that any NARS need consider in designing its research program.

This could change if the nations of the world were to form an agreement to limit methane emissions. Any country signatory to the agreement would be obliged to abide by its terms, which presumably would include control of farm sources of methane. NARS in such countries then would have to consider the methane emission consequences of alternative NRM practices and technologies. In the absence of any such international agreement, however, NARS can comfortably ignore these consequences.

The environmental consequences listed above have both physical and social value dimensions. Both present formidable measurement problems. Techniques exist to measure the sediment and chemical composition of surface waters at various points in watersheds and river basins. It is also possible, although not easy, to measure at least some of the physical consequences of these pollutants for aquatic ecosystems and recreational uses of water. Studies have shown, for example, that sediment deposited in streambeds can disrupt the reproductive cycle of fish in specific ways, and the number of fish killed by pesticides in the water can be counted. Consequences for recreational uses of the water can be measured by changes in the number of days the water is used for fishing, boating, swimming, and other recreational purposes. We have no idea how many LDCs now collect these kinds of data, nor what the costs of collection might be. The work can surely be done however.

Linking the measured environmental consequences to upstream sources presents problems of its own. In many, perhaps most, situations farm production is not the only source of these constituents of the water. Natural erosion, for example, is a universal phenomenon and is often a major source of sediment. Nitrate nitrogen in these waters may be leached from naturally occurring soil nitrogen as well as from nitrogen fertilizers applied to farmers' fields. This is true also of nitrates in groundwater. Some but rarely all of the phosphorus in surface waters may be from urban household and industrial sources. Probably only pesticides in ground and surface waters can confidently be ascribed to farm production, and even some pesticides originate in urban areas.

At first, measurement of the physical environmental consequences of land clearing and draining appears relatively easy: count the number of hectares cleared or drained. In most instances it should not be too expensive to identify the farmers doing the clearing and draining. In fact, however, the measurement problem is not so easily resolved. The amount of land cleared or drained is not the consequence of interest; it is the resulting loss of plant and animal habitat. Measurement of the physical dimensions of this loss would minimally require knowledge of the number and kinds of species of plants and animals inhabiting the affected area. The United States has reasonably good data on the number, kinds, and location of many species of plants and animals in the country. Data are much better for game animals than for others. Linking changes in numbers to farm practices, or to any other activity, however, is a very tenuous matter. The status of this kind of information in the LDCs is less known to us but we doubt that many of them have as much as the United States, and suspect that most have less.

Measurement of the human health consequences of drinking water polluted by agricultural chemicals or animal wastes in runoff from farmers' fields may be easy if the number of affected people is small and they are close to an identifiable source of the pollution. But if the affected people are numerous and widely dispersed through the watershed or river basin, the measurement problem becomes difficult. If the people are also exposed to other health-damaging sources, such as untreated sewage, then assigning consequences to agricultural sources becomes doubly difficult. These same points apply to health effects associated with eating pesticide-contaminated food.

With a sufficient commitment of resources, headway no doubt could be made toward measuring the quantitative dimensions of the various environmental consequences discussed. However, the costs would surely be high.

Because environmental consequences are unpriced, valuing them is far more difficult than valuing NR consequences. Over the past 25 years, economists have developed a variety of techniques to measure the value of the environmental consequences of changes in policies and production practices. The techniques can be as readily applied to the consequences of agricultural practices as to any other kind of production activity. One technique measures environmental values by systematically linking unpriced characteristics of the environment to characteristics of some marketed, hence priced, good or service. For example, the value (or cost) of air pollution has been estimated by statistically relating different degrees of air pollution in an area to differences in house prices. These studies have shown that, controlling for other factors affecting house prices, prices in areas with clean air are higher than in areas with polluted air. The difference is taken as a measure of the marginal social value of clean air. This is indicated by people's willingness to pay more for housing to get it. Such techniques are beginning to be applied in LDCs in both urban (for example, Mexico) and rural (for example, China) contexts.

Another technique, used mainly to estimate the effects of surface-water pollution on recreational values of the water, relates differences in surface-water quality to differences in the cost of traveling to enjoy the recreational benefits of different water bodies. The studies generally show that people are willing to pay more to visit sites with cleaner water. Such studies can be used to estimate the increase in social value of a farming practice that reduces sediment damage to downstream recreational uses of water. One can envisage analogous applications in LDCs such as Nepal. Analyses of this type have already been made of recreational uses of coastal marine resources (Dixon, Fallon-Scura, and Vanthof 1993).

The third technique, and the one now occupying the attention of many resource economists, relies on surveys in which people are asked how much they would be willing to pay to achieve varying amounts of improvement in some aspect of the environment. Studies of this sort have been done, for example, to estimate the value of improvements in animal habitat. (For an authoritative, nontechnical account of the principal issues in using this technique see *Choices,* Second Quarter, 1993.)

These three techniques in effect seek to value the environmental consequences of different activities by estimating what the prices of the consequences would be if they were registered in markets. In principle, therefore, the techniques make the valuing of environmental services, such as the recreational services of clean water, conceptually commensurate with marketed, hence priced, goods and services. The advantage of this for policy making, including agricultural research policy, is that when the techniques work properly the value of the environmental consequences of alternative policies can be directly compared with the value of marketed outputs (or inputs). In the context of this paper, the techniques offer a way, in principle, to combine environmental outputs and inputs with marketed outputs and inputs in the construction of total productivity indexes.

The key question is how to make the techniques work properly. All of them are data-intensive and require highly developed skills in collecting and statistically manipulating large quantities of data. Avoiding bias in the results is a problem for all three techniques, particularly the one relying on surveys of willingness to pay for varying amounts of environmental quality. The survey technique probably is more expensive per unit of reliable information obtained than the other two but it can be applied to a wider set of situations and does not rely on linkages between the market simulated by the survey and actual markets.

The usefulness of these techniques for valuing the environmental consequences of alternative agricultural practices in LDCs depends on specific country circumstances. The kind and scale of the consequences and the access of NARS to the skills needed to properly apply the techniques likely would be most important. Given the critical importance of valuing environmental consequences as a condition for making sound judgments among alternative research strategies, we believe that it would pay at least some NARS, especially those in relatively large countries and those in countries that have attained moderate levels of average income, to explore the potential usefulness to them of these techniques.

## 3.7 Intergenerational Issues, Planning Horizons, and Discounting

Although there are numerous definitions of sustainable agriculture, they all have in common an explicit concern with the intergenerational consequences of current agricultural practices. The implication of concern for sustainable agricultural development is that, in assessing the NR and environmental consequences of alternative NRM practices and technologies, NARS must adopt an intergenerational perspective. This further complicates the already complicated measurement problems. It is not enough to estimate current or short-term consequences. A time horizon measured in decades is required.

A properly prepared demand scenario will cover such a time horizon. It also should provide some guidance to NARS in thinking about possible long-term NR and environmental consequences of alternative NRM and technological responses. Suppose the demand scenario indicates rapid growth in demand for feedgrains over the next several decades and includes estimates of the timing of the demand increase. Agroclimatic information about regions in the country will provide guidelines about where feedgrain production likely would increase in response to rising demand. Knowledge of the feedgrain yield potential with current management practices and technologies would permit estimates of the amount of land likely to be in feedgrain production and the rate at which the land could come into production (Crosson and Anderson 1992, pp. 94-95). These estimates, combined with knowledge of present land uses, would suggest whether forests might be cut or wetlands drained to meet the demand for land for feedgrain production and a desirable time pattern for cutting and draining. Knowledge about soils, terrain, and climate in the affected regions would permit judgments to be made about the effect of increased feedgrain production on soil erosion, given current land management practices and technologies. Knowledge about the hydrology of the affected regions, combined with estimates of the timing of the production increases, would then provide the basis for estimates of the effect of the increase in production on the amount and timing of downstream deliveries of sediment and related agricultural chemicals.

The point of this illustrative material is that a well-drawn demand scenario, which includes estimates of the timing of demand increases, when combined with information about agroclimatic conditions and about current NRM practices and technologies can provide NARS with useful guidelines as to the location, timing, and quantity of various kinds of environmental consequences likely to occur as farmers respond to the demand scenario. Should it appear that the consequences would be inconsistent with sustainability, this would raise a flag signalling to NARS that new NRM practices and technologies will be needed to bring production within sustainable limits.

When the time horizon is over decades, the difficult problem of valuing the NR and environmental consequences becomes even more difficult. Commodity prices will surely change. In countries linked to global agricultural markets, the change will be downward if long-term trends continue. Environmental values will also change, but the lack of prices for these values means that even directions of change over time cannot readily be calculated. There is reason to believe, however, that the values will rise over time. Reasonably strong evidence indicates that as per capita income rises above the subsistence level demand for environmental services begins to rise faster than demand for basic services such as food and clothing. The supply of many environmental services, however, is quite inelastic. Consequently, as the rising demand for the services presses on the inelastic supply, the marginal value of the services rises.

The argument for expecting the marginal value of environmental services to rise is, in the tradition of Runge (1992), largely hypothetical although it is supported by some evidence in the industrialized countries. The strength of the argument in the LDCs is not clear and, in very low-income countries, the argument may not apply at all until later stages of development are attained. Some econometric evidence assembled by Antle and Heidebrink (1991) suggests negative to zero elasticity of demand for environmental quality up to average income levels of about US $1,200, and a relatively elastic demand in middle to high-income countries. Notwithstanding the shallowness of the base of current information, the argument laid out here provides NARS a starting point as they ponder the problem of valuing the environmental consequences of agriculture over the next several decades.

Recognition of the importance of estimating NR and environmental consequences over time introduces the problem of discounting. The question of finding the “correct” rate of discount for less-developed economies has been discussed extensively and inconclusively by economists for at least 30 years (Arndt 1993). Some have argued that, where unique natural assets of overriding social value or the sustainability of basic life-support systems is at stake, intergenerational equity dictates that the correct discount rate is zero and that these assets and systems must be indefinitely preserved in their present state. Pristine tropical rainforests and wildlife reserves are examples of such natural assets. The stratospheric ozone layer, judging from widespread concern, is an example of a basic life-support system. A particularly knotty set of problems in management of these unique assets arises from the uncertainties about possible irreversible losses of them. Suggestions for assessing the additional costs of incorrect decisions that might result in social regret are made by Graham-Tomasi (1985) and Haremann (1989).

The acceptance of the imperative of intergenerational equity in NR and environmental management implies that, in principle, some natural assets and systems may exist that lie outside the bounds where discounting and tradeoffs among resources are legitimate (Toman and Crosson 1991). Note that a large element of social judgment is involved in identifying such assets and systems. In fact, identifying this class of unique natural assets is wholly a social judgment. That is, the rationale for protecting them is not that their loss would imperil the future of the human species on the planet, but that it would unfairly deprive future generations of the enjoyment of them. Social judgments enter also, but to a lesser extent, in the identification of critical life-support systems. These judgments concern the validity of the scientific evidence indicating that natural systems do or do not play a fundamental life-support role and are or are not under threat. No one doubts that the global climate system is fundamental to life as we know it, but social judgments differ widely about the seriousness of the threat to the system from cur-rent and prospective human actions.

Each of the LDCs committed to intergenerational equity will have to decide whether there are, within its borders, natural assets and ecological systems that must be protected against further exploitation and which, therefore, lie outside the bounds of discounting and tradeoffs. Such assets and systems, if such exist, would place constraints on the development process. In designing their research programs, NARS would have to look for improved NRM practices and technologies that would not violate the constraints. There always will be alternative practices and technologies consistent with the constraints. In judging the merits of these alternatives, NARS would and should employ discounting of their future NR and environmental consequences.

We believe that it is likely that most if not all LDCs will identify some natural assets and ecosystems that they will want to place outside the limits of further development. We suspect, however, that the number of such protected assets and systems will be small and that, for most resources, the discounting of development consequences will be appropriate. This leaves open the question of the appropriate discount rate for these resources. In countries where capital markets are well developed, the market rate of discount might be appropriate. At a minimum, the market rate might establish a base from which to consider whether some lower (or higher) rate might be more appropriate.

Page (1988) has written that searching for the correct rate of discount is like searching for the will of a wisp. We agree. We suggest that, in the end, the choice of a discount rate for calculating the present values of the NR and environmental consequences of alternative NRM practices and technologies should be a social decision similar to that of how to assign values to the consequences. In both cases, market information should be used where available, but not necessarily accepted without adjustments to make the market values more representative of “true” social values. With respect to the discount rate, the important point is that the rate selected should reflect a systematic canvassing of all the market and other relevant information. The rate selected will be a judgment call. But some judgments are better informed than others.

## 3.8 Summary on Measurement

We have had two basic objectives in this discussion of the problems of measuring the physical and social value consequences of alternative NRM practices and technologies. One is to identify the most important likely consequences and to show why measurement presents difficult problems, particularly for valuing environmental consequences. The second objective is to demonstrate that, despite the measurement difficulties, NARS are not completely handcuffed in dealing with them. A variety of measurement techniques and bodies of knowledge exist that can be used by NARS to make judgments, albeit possibly rough ones, in sorting out which consequences are likely to be more important and which less. We emphasized the value of the demand scenario in providing guidelines to NARS with respect to the nature, magnitude, location, and timing of future consequences.

The measurement problems are big and complex, and clearly there are no perfect solutions. In the end, judgments must come into play. However, as we noted in connection with choosing a discount rate, some judgments are better informed than others. We have sought to indicate some of the more important tools and sources of knowledge that will enable NARS to make those better judgments.

## 3.9 Understanding the Causes of NR and Environmental Consequences

Measurement of the NR and environmental consequences of alternative NR practices and technologies does not provide NARS with sufficient information to design their research agendas. NARS also need to have some understanding of why farmers sometimes adopt practices and technologies that damage the NR base and environment, or fail to adopt practices and technologies that enhance the productivity of these resources. A NARS research agenda guided only by measurement of NR and environmental consequences could go astray if farmers refuse to adopt the resulting practices and technologies. The importance of understanding farmers' incentives to adopt or not adopt alternative NRM practices and technologies is illustrated by the following quotation from Shaikh et al. (1988, p. I 11) writing about the Sahel:

> There is a sufficient range of technically proven and economically attractive natural resource interventions available to halt the decline of rural production systems in the Sahel. Better technological packages can and should be developed, *but technology is not noiv the limitingJactor in improving small-farmer productivity through natural resource management.* The greater development challenge is to bring about widespread adoption of the appropriate technologies. This is a human issue which has economic, institutional and policy dimensions. (Emphasis added.)

Let us suppose that the statement is valid and that it applies more widely than to just the Sahel. It suggests that in designing their research programs NARS in countries where the quoted statement is valid should carefully canvass the existing situation with respect to the kinds of NRM practices employed and that potentially would be employed if the institutional conditions affecting adoption were favorable. Otherwise, such NARS might find themselves reinventing yet another "wheel" for which there is no demand.

The place to begin the search for understanding of why farmers adopt or do not adopt is the institutional and policy environment that shapes farmers' incentives to invest in new NRM practices and technologies. Addressing this set of issues extends the area of inquiry of most NARS well beyond their traditional range. In section 4.4 we discuss ways in which NARS might deal with this additional intellectual challenge. In this section we consider factors affecting farmers' adoption incentives and a range of cogent policy and institutional links to these.

### 3.9.1 Supply of purchased inputs

We are particularly interested in policies and institutions that differentially affect incentives to adopt improved NRM practices or new commodity technologies. For purposes of discussion, we assume that new commodity technologies generally require more purchased off-farm inputs than do improved NRM practices. It follows that in countries where institutions and policies give farmers reliable and easy access to inputs on favorable price and credit terms new commodity technologies will be relatively more attractive to farmers than will be improved NRM practices. The situation will be reversed in countries where access to inputs is unreliable and expensive. This suggests that in setting priorities between improved NRM practices and new commodity technologies NARS should pay attention to current and prospective policies and institutions affecting the supplies of the purchased inputs required for the new technology. A finding that these policies and institutions weaken farmer incentives to adopt purchased-input-dependent technologies would indicate to a NARS that lower priority should be given to such technologies relative to improved NRM practices. Of course, policies and institutions that favor purchased-input-dependent technologies would strengthen their priority.

Tabor, Quartey Papafio, and Haizel (1992), in a study of the effects on agricultural research of a structural adjustment program in Ghana, cite a World Bank analysis of Ghana that recommends that because of the high prices of purchased inputs, agricultural research in Ghana should focus on developing technologies that do not rely on purchased inputs. Instead, greater research emphasis should be put on developing production systems reliant on cover cropping, use of organic fertilizer, and mixed farming. We do not allude to this analysis because we necessarily agree with its recommendation but because it illustrates the point that, in assigning priorities between NRM and commodity technology research, NARS must recognize the importance of the supply of purchased inputs.

The importance of paying attention to policies and institutions affecting farmers' adoption incentives is perhaps even greater when improved NRM practices and new commodity technologies are complements. Suppose that the productivity payoff to practices to increase soil-moisture retention depends on the availability of a higher yielding crop variety and use of more fertilizer per hectare, and vice versa. Farmers will not adopt the soil-moisture conserving practices and new varieties unless adequate amounts of fertilizer are reliably available on satisfactory terms. Should a NARS invest in developing the two complementary improvements without considering the future supply of fertilizer, it might find its investment largely wasted. Antoine suggests that something like this has happened in Africa (1993, p. 45). He asserts that NARS in Africa have focused on plant breeding programs without taking sufficient account of the fact that in much of Africa there are problems with the availability and multiplication of seeds of the improved varieties and insufficient information to farmers of how to access the seeds and grow them. One can infer from this argument—assuming that it is accurate—that much of the plant breeding investment by African NARS has yielded low returns because of an institutional problem having little directly to do with NARS. In many cases this problem is outside NARS' area of responsibility.

### 3.9.2 Property rights and incentives

Another institutional issue of major importance for the design of agricultural research programs concerns the distribution of property rights in natural and environmental resources. There is a broad consensus in the agricultural development community that farmers' incentives to invest in new NRM practices and technologies is directly related to the clarity and enforceability of their property rights in the resources they use. Without these conditions, farmers or communities of farmers lack assurance that they will reap the gains from investments in improved practices, particularly those such as soil conservation that pay off over the long term.

The property-rights issue is especially relevant to understanding the causes of NR and environmental consequences of farm operations. Natural resource consequences-defined earlier as those that affect the economic costs of production-occur mostly on the farm. Environmental consequences by definition occur off the farm and affect resources in which the farmer ,generating the consequences has no property rights. The farmer thus has no incentive to take environmental consequences into account when considering investments in improved NRM practices and new technologies.

Property rights in the land that farmers use directly in production are not by any means everywhere clearly defined and enforced in the LDCs. To the extent that they are not, farmers' incentives to take account of land-productivity consequences of their operations are weak, just as they are for environmental consequences. Nonetheless, our guess is that, for most of the land at their disposal, the property rights of LDC farmers are sufficiently well defined and enforced to give them incentives to manage the land so as to protect or enhance its long-term productivity. Property rights do not necessarily have to be vested in individuals to meet this condition. Much evidence indicates that common-property systems of land management can be consistent with conserving uses of the land if community rules governing individual or family access to the land are clear and enforced.

We do not mean to suggest that clear and enforceable property rights are sufficient conditions for NR-conserving on-farm practices. Farmers with very low resources who live on the thin edge of subsistence may feel that they have no choice but to mine the meager resources available simply to survive. These farmers might well recognize that their practices are not sustainable. But if one does not survive in the short-run, the long-run is not of much interest.

How many LDCs farmers live in this perilous condition is unknown, but the number is surely large. The plight of these farmers does not make irrelevant the argument that property rights strongly affect farmers' investment incentives. But establishing clear and enforceable property fights for these farmers will not in itself do much to improve their lot. They need more resources.

The difference between on-farm and off-farm property rights regimes has important implications for the research strategies of NARS. The difference implies that the only way that NARS can contribute to reducing negative, or enhancing positive, environmental consequences is by developing NRM practices and commodity technologies that have those effects and also are profitable to farmers. This role for NARS may appear unsurprising, but it bears further consideration. Changing on-farm NRM practices and technologies may not be the most economically efficient way to deal with the environmental consequences of agricultural production. For example, much evidence (Crosson 1986) exists to show that reducing on-farm erosion is not necessarily the most efficient way to reduce downstream sediment damage. Much of the soil eroded from farmers' fields is stored throughout the watershed or river basin, including stream beds. When erosion on farmers' fields is reduced, with consequent reduction in the sediment load in farm runoff, the released energy permits the water to pick up sediment stored off-farm and deliver it downstream. Downstream sediment damage thus can continue unchecked for long periods—years and decades—despite a decline in on-farm erosion.

In these circumstances, NARS' resources devoted to developing erosion-reducing practices and technologies to reduce downstream sediment damage likely would generate unfavorable cost-benefit ratios. The opportunity costs of not investing in on-farm alternatives with more promising short-term potential could be high. And benefits, even if eventually substantial, would be heavily discounted because they were delayed so long.

This, of course, is not to argue that the environmental consequences of agriculture can or should be ignored. It is to say that putting the full burden of dealing with the consequences on NARS may not, in many instances, be the most efficient way to go. With respect to downstream sediment damages, for example, there are several techniques by which sediment-laden waters can be intercepted or diverted before they reach lakes, reservoirs, or other water bodies where they cause damage. Check dams, holding ponds, and filter systems are examples of structures that slow or hold the water long enough to permit the sediment to settle out. Of course, these structures have economic costs, and the collected sediment must be disposed of from time to time; but disposal can be in places with little if any alternative uses of social value.

Dealing with the environmental, which is to say off-farm, consequences of agricultural production through off-farm measures would require appropriate policies and perhaps new institutions. For example, a basin-wide authority might be established with powers to decide where and how in the basin to intervene to control sediment damage and with powers also to levy taxes and fees on farmers in the basin and on beneficiaries of reduced sediment damage. The responsibility for containing sediment damage within acceptable limits would, however, lie with the river basin authority, rather than with the NARS.

The message here is that some policies and institutions differentially affect farmer-perceived rates of return to investments in improved NRM practices and new commodity technologies. To properly weight returns to research on these practices and technologies, NARS need to be aware of farmer perceptions and of the policy and institutional conditions that shape them. We focused on two sets of policies and institutions: those affecting the terms of supply of off-farm purchased inputs and those determining farmer property rights in natural and environmental resources. Our discussion points to several tentative conclusions:

- If input policies and institutions are weak and the success of commodity research depends on purchased inputs, then NRM research might be a better investment than commodity research;
- If commodity research and NRM research are complementary, then poor policies and weak institutions lower the return to both kinds of research;
- Strengthened farmer property rights will raise returns to both types of research;
- Research to find ways to reduce off-farm losses caused by on-farm practices will only be used if farmers also benefit from the solutions developed;
- Attacking some problems (such as downstream effects of soil erosion) at the farm level may not be the most efficient solution. It may be more efficient to increase productivity on the farm and find other technical and institutional means to reduce the damages of sediment downstream.

# 4. DESIGNING AND IMPLEMENTING THE RESEARCH AGENDA

## 4.1 Introduction

Joining estimates of the principal NR and environmental consequences of alternative NRM and commodity technologies with estimates of the corresponding economic consequences, and with some understanding of the effects of policies and institutions on farmers' incentives to adopt the various alternatives, NARS now are in a position to assign research priorities among the alternatives and to undertake research on them.

Three aspects of the NARS' task are discussed in these respects. One concerns the handling of uncertainties about research outcomes in assigning priorities among the several potential lines of research. The second aspect discussed is the question of the extent to which the research, in the interest of equity, should focus on resource-poor regions at the cost of gains in total productivity across the nation as a whole. Finally, we devote considerable attention to the capacity of NARS to conduct the needed research as well as to how that capacity might be strengthened.

## 4.2 High Potential/Low Potential Regions

In most if not all LI)Cs, some regions are more favored by climate, soils, and terrain to produce agricultural output than other regions. It often is assumed that the total productivity payoff to a unit investment in research typically is higher in the more favored regions than in the less favored regions.

We can think of only two reasons why it would ever make sense for a NARS to focus its research on the less favored regions. One is that the total productivity potential of the more favored regions is about used up by previous productivity gains. This means that the apparent advantages of climate, soils, and terrain are illusory. Remember that, in judging the total productivity potential of more favored relative to less favored regions, the NR and environmental consequences of production in the two regions must be taken into account. Comparison of potential yield increases will not suffice. Since less favored regions are likely to have a greater erosion hazard than more favored regions, the total productivity potential in the more favored regions could be greater even if interregional differences in yield potential were negligible.

We are proposing a revised definition of "more favored" and "less favored" regions. Our point is that a more meaningful sense of these expressions is "more productivity potential" and "less productivity potential," indicating that interregional differences in climate, soils, and terrain are not sufficient to define more and less favored regions. Consequently, the first reason for focusing, on less favored regions is no reason at all. In the absence of any other considerations it would never make sense to focus on less favored regions as we define them.

The second reason for focusing research on less favored regions is that concerns about equity in the distribution of productive opportunities outweighs productivity gains as the criterion for the research focus among regions. This is largely a political criterion and one that many LDCs appear to be sensitive to.

The implication of our revisionist view of how to define more or less favored regions is that the equity argument is the only valid argument for ever focusing research resources on less favored regions. Whenever the argument is used to shape regional research strategies, the NARS, or whatever authority is setting the NARS research priorities, has, in effect, made a political decision that the social welfare of the country would be advanced by generating more income in the less favored region even at the cost of some loss of national income. (We assume here that advancing the national welfare is the objective of national agricultural research policy.)

Such judgments clearly are within the purview of the political authorities of countries. It is not so clear, however, that the best way to serve equity is to focus research on less favored regions. Equity might in some circumstances be enhanced more by focusing agricultural research on more favored regions and promoting migration from the poorer regions to take advantage of the increased job opportunities in the richer regions. Indeed, policies to expand nonagricultural activities in urban areas may be even more effective in improving the lot of people in the less favored regions.

Of course, the effectiveness of these alternative options depends on whether people are free and capable of moving from one region to another. It also depends on the feasibility of expanding job opportunities in more favored agricultural regions or in urban areas. Obviously these conditions will vary from country to country. However, when NARS are thinking about shaping their research program to promote equity, they should recognize that focusing the program on less favored regions is not necessarily the most cost-effective way, to accomplish that objective.

## 4.3 The Capacity of NARS to Do the Work[2]

We have described three kinds of knowledge that NARS should have to design efficient research programs incorporating not only the commodity consequences of production but also the NR and environmental consequences: the kinds of NR and environmental consequences likely to be important, both physical and value measurements of the consequences, and an understanding of the conditions governing farmers' incentives to adopt improved NRM practices and technologies designed to bring the consequences within acceptable limits.

A critical remaining question concerns the capacity of NARS to acquire the three kinds of knowledge and to use it efficiently in developing their research programs. This is the question addressed in this section. We first consider the kinds of professional skills needed to build the three kinds of knowledge. We then consider how NARS might best go about mobilizing the needed skills and using the knowledge acquired to shape their research programs. It should be obvious that our approach to NR and environmental research policy issues recognizes that every country is unique and that individual circumstances will shape the individual needs and the set of optimal institutional responses—a set that will surely be highly diverse.

### 4.3.1 Kinds of needed skills

A recital of the principal NR and environmental consequences-soil and water degradation or enhancement, habitat losses or improvements, downstream effects of sediment and agricul-

2 For an excellent discussion of the sorts of issues considered in this section, see Oram (1992).

tural chemicals on various uses of surface water, human health effects of agricultural chemicals in ground and surface water and of pesticide residues in food-suggests many of the needed skills. Soil scientists, hydrologists, entomologists, civil engineers, ecologists, and chemists are only a few. Measurement of the social values of the consequences requires people from the social sciences as well, mainly economists. Gaining the needed understanding of farmers' incentives to invest in improved NRM practices and new technologies draws in a wider cadre of social scientists, including economists but also rural sociologists, anthropologists, and political scientists. Of the several institutional components of NARS, it is usually the universities that art, best endowed with such a range of disciplinary skills.

We have emphasized the importance of a demand scenario as a guide to the magnitude and kinds of pressures that the agricultural system might face in the future. Constructing such a scenario is a task for economists knowledgeable about the effects of population growth, per capita income, and local, national, and possibly international preferences for the kinds of agricultural output the country produces, or potentially could produce.

The list of needed skills presented here may not be complete, but is fairly comprehensive. It is a formidably mixed set. How might NARS mobilize these skills and use them efficiently in their research programs? Detailed answers to the question are outside the bounds of this paper. There are some general answers, however, that might help NARS to think through this problem.

### 4.3.2 Mobilizing the needed skills

It is unlikely that many NARS would have the resources to represent all the needed skills on their staffs. Perhaps the biggest NARS—such as those of China, India, Indonesia, Brazil-could come close. But even if they could it might be inefficient that they should, at least not without first canvassing the possibilities of finding the skills elsewhere—in the private sector and in other national and international agencies on a custom hire or some other mutually satisfactory basis.

In a review of numbers of different kinds of scientific skills engaged in agricultural research in the LDCs in the 1980s, Oram, (1992) counted 36,025 scientists in eight fields: crop sciences, resource management, technology, social sciences, animal sciences, fishery science, forestry, and miscellaneous. They were distributed among the four major regions—Sub-Saharan Africa, South-Southeast-East Asia, West Asia/North Africa, and Latin America—as follows:

| Region | Percent |
|---|---|
| Sub-Saharan Africa | 14 |
| South-Southeast-East Asia | 14 |
| West Asia/North Africa | 19 |
| Latin America | 23 |

The distribution of the 36,025 scientists among the eight fields distinguished by Orarn was in percentages as follows:

| Field | Percent |
|---|---|
| Crop science | 33.3 |
| Resource management | 13.2 |
| Technology | 5.9 |
| Social sciences | 6.5 |
| Animal sciences | 14.4 |
| Fishery sciences | 10.0 |
| Forestry | 14.8 |
| Miscellaneous | 1.9 |

The relatively high percentage of scientists in crop sciences no doubt reflects the heavy emphasis given to that specialty in agricultural research over at least the past 40 years. We have no idea what the optimal distribution of skills would be to deal with emerging NR and environmental consequences of agriculture in the LDCs. We suspect, however, that it would include substantially greater percentages in resource management and the social sciences. Resource management, as Orarn defines it, includes plant nutrition, soil chemistry, and physics, as well as water management, ecology, climatology, and geography. Presumably research on the productivity effects of soil degradation and of water pollution would be included in this field. A number of NRM systems with promising productivity potential involve mixed crop-livestock and crop-livestock-forestry combinations (National Research Council 1993). Tapping the productivity potential of these mixed systems would draw heavily on skills in forestry and animal science, as well as in crop science.

Oram singles out the low representation of social sciences among the eight fields as “the preeminent area of weakness” in agricultural research in the LDCs. Among the relatively few social scientists represented, most are economists.

The limited numbers of social scientists involved in agricultural research are not evenly distributed across the LDCs. It is not uncommon to find NARS with literally no social scientists. Since the social science dimension of comprehending natural resource degradation and management issues generally is so central, the lack of this expertise creates major potential difficulties for the formation of relevant research groups. In some nations, especially small ones, most of the social scientists—in many cases these are almost all economists—are to be found within the national planning agencies. These may not be closely linked to NARS or other relevant line agencies, such as the soil conservation service and extension service. Of even greater scarcity are national agricultural economic research agencies that are attuned to the broad responsibilities implied by NR and environmental research. There are some exceptions, however, and cases such as the Bureau of Agricultural Economics of the Philippines are notable for the example they can provide to other LDCs as a model for cost-effective social science research administration and agricultural policy analysis, including specifically natural resource management policy.

We share Oram’s view that adequate treatment of NRM and environmental issues in the LDCs will require a substantial increase in the number of social scientists engaged in agricultural research, both in absolute numbers and relative to other scientific disciplines. We are less concerned than Oram. seems to be if the greater part of the increased number were economists-perhaps a professional bias shows here—but we are convinced that other social science skills will be needed also.

Present and prospective NARS budgets will not permit the increase and change in the composition of scientific staff that will be needed to deal adequately with prospective NR and environmental issues. There may, however, be some prospects for attracting additional resources to work on these issues. Concern with the issues among donor agencies and in the CG system could mean a greater flow of externally provided funds for research on these issues. NARS thus need to stay aware of the possibilities of enticing forms of assistance under new headings from international, multilateral, and bilateral assistance programs.

Since part of the essence of the approach to NR and environmental issues is the improvement of total productivity by drawing on appropriate global and regional research, NARS also need to be especially alert to the need to draw on work done elsewhere that may have relevance to their particular circumstances. As well as the forementioned international assistance, the possibilities for cooperation between nations sharing similar NR and environmental problems need active exploration. There are, indeed, several regional initiatives presently underway in sub-Saharan Africa designed to facilitate just such cooperation and rationalization of scarce research resources and their diversion to common problems. Such arrangements are not costless, but have the potential to be economical in fostering significantly improved efficiency in the use of research resources.

A key feature of the approach to NR and environmental issues being adopted in the CGIAR system is the strengthening of cooperation with NARS by subsets of the IARCs. It is important then for individual NARS to realize that they are not alone in facing their challenges and that assistance, albeit highly circumscribed in the current financial climate, is available if it can be orchestrated.

However much these potential sources might supplement NARS' budgets, the total still most likely would be insufficient to fund the increase in social science and other skills that will be needed. It will be imperative, therefore, for NARS to find ways to reach out and tap the needed skills in other public and private-sector agencies. This will be no easy task. Oram (1992) points out that, throughout the LDCs, responsibilities for higher agricultural education, research, extension, and information are fragmented among federal and provincial governments, ministries, autonomous agencies, and public institutions, including universities. Moreover, new ministries created to deal with NR and environmental issues have research agendas not linked to those of the NARS. The resulting lack of coordination may lead to waste of the already limited resources available for agricultural research.

Oram (1992) notes that some of the larger LDCs have sought to deal with the lack of coordination in agricultural research by creating interdisciplinary agricultural research councils with representation from the concerned ministries to coordinate or, in some cases, to manage research. For small countries, however, this approach may be too costly (Oram 1992). An aspect of the coordination problem is the difficulty of achieving effective implementation of research activities across provincial or state boundaries within a national system. In some countries where there seems to be clear scope for this, such as Pakistan, there is not a strong tradition of active research themes that cross such provincial demarcations and it may be that a national-level thrust is needed to achieve such work effectively. The idea of a national agricultural research council, with an appropriately broad mandate is clearly one that can facilitate such an endeavor. Pakistan, for instance, has such a council and, indeed, some thematic research is organized in this way. Usually, however, this has more to do with commodity research programs that naturally apply across provinces and has much less to do with the type of location-specific agronomic and other research where the agroecological zones span provincial borders.

Some of the most stubborn problems in linking NARS with agencies that have natural resource management responsibilities are due to seemingly arbitrary decisions made in constitutional drafting concerning the responsibilities of different levels of government. In much of South Asia, for example, agriculture is deemed to be a state responsibility and indeed nearly all agricultural policy must be implemented at the state government level. Science and technology, however, is deemed to be a national responsibility and hence there is a clear conflict between competing elements of state and national bureaucracies. The innovation of a national research council, usually linked to a declared national science and technology policy, provides one vehicle for addressing these issues and for bringing nationally funded research and development activities to the state instrumentalities. The difficulties have, in a general way, been fairly well resolved in most countries, although continuing problems are to be found in some nations.

These solutions to the institutional coordination problem have occurred in circumstances where agriculture was defined as an activity occurring on the farm and involving measured inputs and outputs. However, the more expansive definition of agriculture to embrace NR and environmental consequences of farm operation creates new institutional challenges. As noted above, many governments, especially in the post-1992 UNCED era, are moving towards institutionalizing national environmental protection authorities (EPAs) that have umbrella responsibilities for environmental issues, including those related to the agricultural resource base. These are typically invoked first at the national level and then, subsequently, at a second level, such as the provincial or state level, with corresponding legislative mandating of particular responsibilities. The new institutional challenge thus is to link national and state-level research and development activities in an appropriate way to inform and underpin policy and the intervention sought by the various EPAs or their conceptual equivalents. There is not an immediately obvious bureaucratic match between NARS and EPAs. This is particularly because there is usually different ministerial responsibility for the agricultural, and maybe even the science and technology elements, as well as for the environmental protection elements.

The most obvious way of dealing with such institutional mismatches is to “go to the top”, especially in societies that are highly centralized in their decision-making and power bases. In some cases, this will mean that the president will need to be persuaded of the necessity for work to be integrated across ministerial domains so that effective working alliances can be forged in the relevant ministries, departments, and authorities.

For natural resource management per se, integration will usually require the formation of a particularly high-level committee, perhaps with direct reporting lines to the office of the president or prime minister, to represent the line agencies that are directly relevant. This is particularly difficult in some cases because representation from agencies that are yet to be organized to address NRM and environmental work frontally will be neither clear-cut nor very influential. There are at least two likely difficulties in NARS. Many NARS are organized essentially on a commodity basis and do not always feature divisions or departments specifically addressed to the biophysical relationships of NRM. In some cases, soil conservation authorities being the classic ones, they are even under separate ministerial direction and departmental structures. Fortunately, these limitations can be readily recognized and addressed in the formation of appropriate intergovernmental working groups and advisory committee structures. The latter would hopefully include strong farmer representation.

The discussion has dealt with problems that the NARS will confront in extending their capacity to deal with NR and environmental issues by tapping other public institutions for knowledge and scientific skills. In many LDCs, the private sector also may be a source of some of the knowledge and skills that the NARS cannot provide or cannot provide as cheaply. In many LDCs, nongovernmental organizations (NGOs) are actively involved in rural areas working with farmers and other rural people to develop social organizations that provide stronger incentives for adoption of improved NRM. These NGOs could be valuable sources of information for NARS seeking a better understanding of farmers' decision to adopt or not adopt alternative NRM practices and technologies.

ISNAR (1993, p. 3) observes that Agenda 21 puts major emphasis on a farmer-centered approach as the key to achieving a sustainable agriculture in the LDCs. With respect to research this implies use of local knowledge about NRM as an important element in the NARS' research agenda. ISNAR sees this as "similar to the philosophy of cropping systems, farming systems, and resource management research as practiced by national systems and international centers. But it goes somewhat further in associating local organizations with the effort. Particular importance is attached to the role of women."

Making use of local knowledge is particularly relevant to research on NRM and environmental issues because that research typically is more site specific than commodity research. Through long experience farmers have acquired detailed knowledge of how to manage their resources under those site-specific conditions. In designing research to increase productivity by altering the conditions, NARS often could use local farmer knowledge to anticipate the productivity responses to alternative practices and technologies.

An agricultural extension service would be one obvious institutional mechanism for systematically tapping farmer knowledge and passing it to those in NARS who could make the best use of it in implementing the research agenda. But extension services in the LDCs are notoriously weak. Moreover, in many countries elitist attitudes among professionals in public agricultural agencies convince extensionists that they have little to learn from farmers, particularly those who are poor, uneducated, and lacking in social standing. Finally, the relationship of people in public natural resource agencies with farmers often is one of antagonism rather than cooperation. In many instances, agency people see their responsibility as enforcement of regulations governing the use of natural resources and collection of fines from farmers who violate the regulations. Judgments of what constitutes violation are heavily weighted in favor of the agency people, who have been known to pocket some or all of the fines they collect. This kind of relationship does not promote the free flow of farmer-to-NARS knowledge.

Strengthening extension services and changing attitudes and practices in public natural resource agencies dealing with farmers would help to overcome these obstacles to the flow of farmer knowledge to NARS. But these reforms, even if vigorously pushed, would not yield results quickly. Without denying the value of such reforms, we believe a more promising way for NARS to collect farmer knowledge may be through NGOs working in rural areas. The objective of many of these NGOs is to increase the productivity of poor farmers by fostering improved NRM practices. Pursuit of this objective puts these NGOs in close contact with their poor-farmer clientele. They thus learn what the farmers know about NRM and have an interest in passing the knowledge to NARS. Of course, NGOs are not immune to corruption and exploitation of the people they ostensibly serve. We doubt, however, that this characterizes many of the NGOs working in rural areas of LDCs. At a minimum it should pay NARS to explore the possibility that these NGOs could channel useful farmer knowledge of NRM practices and consequences to them.

### 4.3.3 Conclusion about NARS' capacity

The above discussion suggests a number of conclusions:

- NARS need more social scientists, particularly economists, trained in natural resource and environmental management and policy. NARS generally are much better equipped to do commodity research than NRM research. This is not to say they have all they need to do commodity research. NARS in Africa in particular still are weak in this respect. But their most glaring inadequacies concern NRM research. Lack of capacity in the social sciences, particularly economics, is most prominent, but the kinds of natural science skills needed to understand the environmental consequences of different farming practices and technologies also are in short supply. In economics the most acute shortage is of economists trained in analysis of natural resource and environmental management and policy. Economics training in the LDCs generally has slighted this aspect in favor of macroeconomics;
- To mobilize the skills they will need and do not now command, NARS will have to tap a variety of international and national agencies, both public and private, some of which have no direct interest in or responsibilities for agriculture. We have mentioned national environmental protection agencies as an example of institutions whose responsibilities overlap the expanded responsibilities of NARS. Such institutions may have some of the skills NARS will need and do not now have in sufficient supply. We also discussed the potential value to NARS of tapping farmer knowledge of NRM practices and consequences, and the possible use of NGOs as the institutional mechanism for overcoming present public-agency obstacles to the flow of this knowledge from farmers to NARS;
- Coordination among agencies and disciplines presents a major challenge. ISNAR's broad definition of NARS to include all agencies, public and private, somehow engaged in agricultural research suggests formidable problems of coordination just to accomplish fruitful commodity research. Introducing NR and environmental issues to the NARS' research agenda probably squares, at least, the institutional coordination problem. We suggested above that, in some cases, a solution to the problem might require creation of a supra-institutional coordinating agency reporting directly to the president or prime minister;
- NARS should be aggressive in defining the NRM/commodity research agenda. Clearly there is no generally "best solution" to the problem of mobilizing the skills and other resources that NARS will need. Indeed, there might not even be any "very good" solutions. We believe it very important, however, that NARS should be aggressive in taking initiatives to find "workable" solutions. NR and environmental issues inspire boldness and assertiveness among many in the international and national communities concerned with economic development. If NARS adopt a reactive instead of proactive posture in dealing with these issues as they touch agriculture, they will risk loss of control of the agricultural research agenda. Despite their weaknesses, the NARS, working in partnership with the IARCs, are, in our judgment, best equipped to find sustainable agricultural development paths for their countries. They should be assertive in taking the lead in seeking those paths.

# 5. STRATEGIC ISSUES FOR THE NARS: RESHAPING NARS'PROGRAMS

Incorporation of natural resource and environmental consequences of agriculture as an integral part of their research program will present a major challenge to the NARS. There is no blueprint to offer as a guide to meeting the challenge. However, several strategic issues have been identified that we believe NARS inevitably will have to address. The act of addressing them may assist NARS in thinking through how they might effectively deal with the emerging challenge.

## 5.1 Taking NR and Environmental Issues Seriously

Everything we have written to this point has been based on the implicit assumption that NARS are prepared to take seriously the arguments for incorporating NR and environmental issues in their research programs. But are they? Some, perhaps many, LDC governments still consider concern about the effects of agriculture on the natural resource base and environment a rich-country luxury that they cannot afford. These governments insist that for them the top priority for agricultural research is to increase yields, more or less regardless of the NR and environmental consequences. Yet other nations see the issue quite differently (Dorji 1992).

If this rich-country-luxury attitude is, in fact, widely and strongly held in the LDCs-and in NARS—then the greatest challenge in this area may be to persuade NARS that the attitude is inappropriate—perhaps dangerously so.

We believe that the best approach to this issue is to make clear that by no means must NARS accept the apocalyptic view of impending NR and environmental disaster expressed by some members of the national and international environmental communities. Nevertheless, there may be some NR and environmental consequences of agriculture of sufficient importance to the welfare of the nation, and not necessarily only in the long run. These should be taken seriously. The concept of total productivity can be useful in making this point. The concept makes clear that, in their implications for the public welfare, the costs and benefits of the NR and environmental consequences of production are no different from any other costs and benefits. That NR and environmental inputs and outputs are not priced, while commodity inputs and outputs are, is irrelevant to the public welfare. No NARS would argue that the country can be indifferent to the quantities of priced inputs and outputs of agriculture. Once they understand the concept of total productivity, NARS should recognize that, for the same reasons, they cannot be indifferent to unpriced NR and environmental inputs and outputs.

Acceptance by NARS that NR and environmental inputs and outputs should be included in the concept of total productivity would be a major advance for NARS in gaining perspective on NR and environmental issues. Questions of valuing the inputs and outputs, however, would still need to be addressed. The countries themselves must make these valuations. We suggested as much in our discussion of assigning values to NR and environmental consequences and to discount rates. We now make that explicit. Our earlier discussion emphasized that the valuation decisions involve much judgment. Those judgments must be made by the responsible people in the LDCs, maybe within a NARS, maybe in some other agency, such as a finance ministry for, say, discount rates. The nationals of a country are qualified to make decisions about which, if any, natural resources are of such great current and future social value that they should be protected against exploitation for economic development. Similarly, nationals are qualified to decide that the social costs of, for example, pesticide pollution are so high that a major share of research resources should be devoted to development of technologies to reduce the costs.

The pesticide example is pertinent because some countries, such as the United States, have adopted policies of not exporting to LDCs any pesticides that it has banned for use within its own borders. In effect, the exporting country presumes to decide that the environmental costs of pesticides in a would-be importing country are inconsistent with that country's best interests. Such policies emit more than a whiff of colonialism.

## 5.2 Strengthen Analytic Capability in NR and Environmental Economics

If NARS are to meet the emerging challenge to their research programs they will have to strengthen their capability in natural resource and environmental economics. Dealing adequately with the difficult problems of identifying, measuring, and valuing the NR and environmental consequences of agriculture requires expertise in that discipline. NARS currently lack capability in this branch of economics (as well as in others). This creates a critical gap. The gap will have to be filled to get the broadened research task done.

But the NARS will need capability in NR and environmental economics also so that they will be able to "hold their own" in their dealings on NRM issues with sister institutions in the CGIAR and with the World Bank, the US Agency for International Development, and other donor agencies. The argument applies equally for NARS' dealings with the numerous NGOs engaged in work on NRM issues. Concern about these issues will not go away. If NARS are to participate as acknowledged equals in the ongoing discussions and, inevitably, controversies in this area, and, if they are to defend their interests, they must have command of the economics of the issues.

NARS will be able to accomplish much of what they want to do in the area of natural resource and environmental economics by contracting experts on an as-needed basis. But to do this efficiently, and perform other critical tasks in this area, in our judgment, NARS probably will need to add full-time NR and environmental economists to their staffs. NARS will not themselves have to do everything that will need doing in this area, but they will need people who understand what must be done and who can take the lead in organizing to get it done.

## 5.3 Taking a Leadership Role

In section 4.4 we argued that NARS risk loss of control of the agricultural research agenda unless they take the leadership in defining the terms of the discussion of NRM issues in agriculture. Environmental protection agencies, environmental NGOs, and, perhaps, donor agencies will not be reticent in expressing views about environmental policies affecting agriculture, and even in prescribing the kinds of NRM practices and commodity technologies that NARS should develop. NARS inevitably will have to respond to these various pressures and, of course, should seek to do so in a constructive way. But if it can be assumed that NARS are best positioned to decide how to find and stay on a sustainable path for agriculture, then they must ultimately decide the appropriate agricultural research program. This role will not be easily ceded to them by the various contending forces. They will have to earn it by demonstrating that they have not only the technical skills but, at least as important, the organizational, and even the political skills needed to get the job done.

To perform this leadership role. NARS must keep unwavering attention on the importance of getting the best feasible estimates of both the economic and the NR and environmental costs and benefits of alternative NRM practices and commodity technologies. Because the environmental costs and benefits are so difficult to measure, wildly varying estimates of them are possible, even usual. Experience shows that environmental agencies, particularly environmental NGOs, tend to discount, if not ignore, the benefits and to emphasize costs. NARS must recognize the importance of this issue and have the technical competence-or know where to get it-to distinguish the better from the worse estimates of benefits and costs. Here it will be critical that where NARS lack the necessary expertise, they can locate it in other national or international agencies.

To this end NARS can identify the principal institutional actors in the NRM and environmental fields and devise ways to tap the expertise of these actors and enlist their support in shaping the agricultural research agenda along lines that NARS think are most appropriate. The larger and more experienced NARS perhaps already know how to maneuver in this field. The smaller, less sophisticated ones probably do not.

One way to tap external expertise is to forge links with all the significant non-NARS institutional actors by actively seeking contacts to include at least the national body or bodies responsible for environmental matters. Those institutions engaged in or with responsibilities for natural resources management should definitely be included. Among public institutions, some of these are the environmental protection agency, the departments of forestry and water resources, the soil conservation service, the fish and wildlife service, and any other service relevant to NR and environmental management. Also useful are contacts with individuals and university departments engaged in social science and natural science research relevant to NRM.

Establishing and nurturing these various contacts is no trivial exercise for NARS even in small countries. We are convinced, however, that the payoff would be substantial in strengthening NARS' abilities to forge the interinstitutional ties they will need if they are to successfully assert their leadership on NRM issues relevant to agriculture.

In section 4.4 we argued that NGOs active in rural areas could be a useful conduit for the flow of NRM and environmental information from farmers to NARS. The argument was based on the implicit assumption that farmers generally are very knowledgeable about NRM in their operations, given the resources, including the human capital, at their command. The argument also rests on the apparent fact that, in most LDCs, there are bureaucratic and attitudinal blockages to the flow of farmer-to-NARS information through extension and other public agencies.

## 5.4 Coordination of NARS with IARCs[3]

The drive in the CG system to give more attention to NRM and environmental issues means that the IARCs in general are beginning to strengthen their capacities in this area. The

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3 For a useful discussion of some of the issues here see IAC/Center Directors' Working Group (1993, Annex 1, pp. 4-6).

NARS should take steps to tap this emerging body of NRM and environmental knowledge that the IARCs are accumulating (as well as the knowledge they already have accumulated). We recognize that the IARCs already have long-standing relationships with NARS. And no doubt the relationships now are being broadened to include more IARC-NARS attention to NRM and environmental issues of mutual interest. Our suggestion is that the NARS should actively seek to strengthen their ties with IARCs to facilitate transfer of knowledge about NR and environmental management.

IARC work on NRM and environmental issues, including such activities as the development of GIS databases, is direclty relevant to NARS. Other IARC work of direct interest would be any analyses of how to set priorities between NRM research and commodity research in the research agenda.

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Concerns for Sustainability: *Integration of Natural Resource and Environmental Issues in the Research Agendas of NARS*

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